

PCT

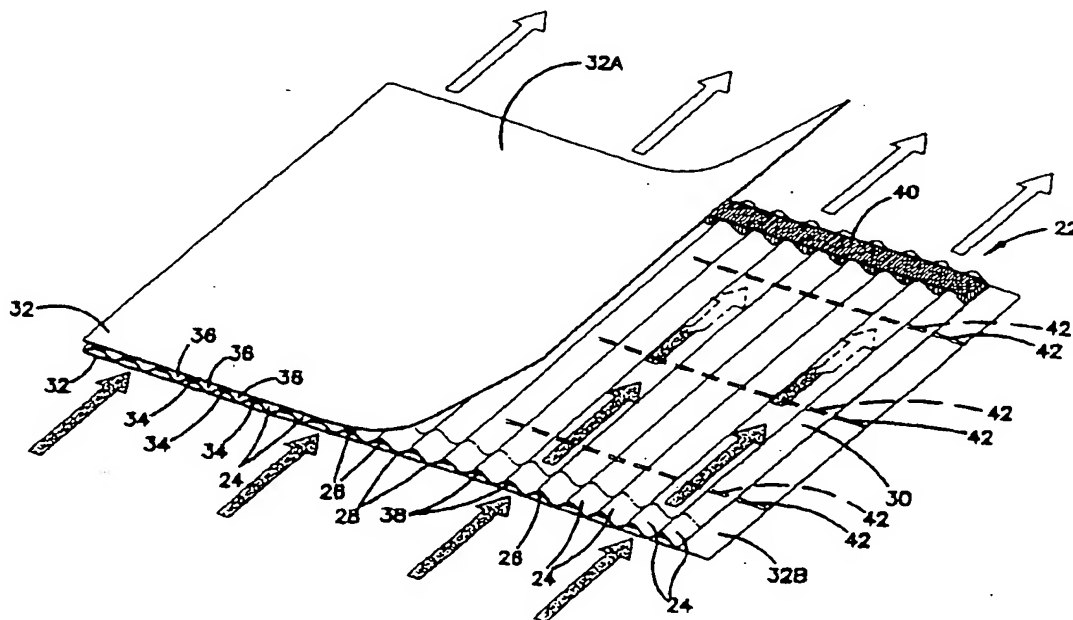
WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B01D 46/12, 46/52, 25/24		A1	(11) International Publication Number: WO 97/40917
(21) International Application Number: PCT/US97/06612		(43) International Publication Date: 6 November 1997 (06.11.97)	
(22) International Filing Date: 24 April 1997 (24.04.97)		<p>(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (OH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</p>	
(30) Priority Data: 08/639,371 26 April 1996 (26.04.96) US			
(71) Applicant: DONALDSON COMPANY, INC. (US/US); 1400 West 94th Street, Minneapolis, MN 55440-1299 (US).			
(72) Inventors: GILLINGHAM, Gary, R.; 17305 Flemming Lane, Prior Lake, MN 55372 (US). WAGNER, Wayne, M.; 120 Redwood Drive, Apple Valley, MN 55124 (US). TOKAR, Joseph, C.; 6205 - 137th Street, Apple Valley, MN 55124 (US). RISCH, Daniel, T.; 1116 - 136th Street West, Burnsville, MN 55337 (US). ROTHMAN, Jim, C.; 332 Riverwoods Lane, Burnsville, MN 55337 (US). WAHLQUIST, Fred, H.; 8444 - 11th Avenue South, Bloomington, MN 55420 (US).			
(74) Agent: BRUESS, Steven, C.; Merchant, Gould, Smith, Edell, Welter & Schmidt, P.A., 3100 Norwest Center, 90 South Seventh Street, Minneapolis, MN 55402-4131 (US).			

(54) Title: INLINE FILTER APPARATUS



(57) Abstract

A filter device inserts into a duct having flow passing from upstream to downstream. The filter device includes fluted filter media having flutes (24) formed therein. The filter forms a seal between the outer edge of the filter and the downstream side of the duct. The filter media may be rolled or stacked in layers to match the shape of the duct.

BEST AVAILABLE COPY

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

## INLINE FILTER APPARATUS

### Background of the Invention

#### 1. Field of the Invention

The present invention relates to a filtering apparatus, and in particular, to a  
5 filtering apparatus having fluted filtering media which is placed inline into a duct or  
other passage.

#### 2. Prior Art

Filters which are placed inline for filtering gases or liquids are well known and  
are commonly utilized for many types of filtering applications. Although prior filter  
10 devices are able to satisfactorily filter a substantial portion of the particulate and other  
materials from gases and liquids, still further improvements are possible. Filtering  
efficiency, especially for small particles and soot, and pressure differential across the  
filter are critical in many filtering applications.

A common problem with filter designs is inadequate filter surface area. Prior  
15 attempts to improve the effective filtering surface area for a given volume of filter have  
not been entirely successful. Pleated filters are commonly used which utilize a pleated  
filter media. Although pleated material may increase the filter area, as the pleats are  
placed closer and closer together, and more and more filter media is placed in any  
given volume, the pleats are pressed tighter and tighter together, thereby restricting the  
20 flow. As the velocity of the flow must increase to pass through the filtering media,  
pressure differential across the filter increases. This may cause additional problems,  
especially in certain engine and turbine filtering applications.

As with pleated filters, most permeable filtering media does not provide  
structural support. Therefore, the filters require structurally-supporting housings for  
25 the filter materials. The additional mass of the housing increases the weight and cost  
of the filter. There may be applications wherein only a simple seal is needed between  
the duct and outer membrane of the filter element to effect an enclosed chamber for the  
filtered fluid, but a heavier housing must be used to support the filtering media.

In addition to the problems of prior filters relating to pressure differential and  
30 media area, prior filter designs are not adaptable to a wide variety of shapes and cross  
sections. In particular, there may be applications where an increased flow receiving  
area having improved flow distribution for an inline filter may be required. Such a

WO 97/40917

PCT/US97/06612

2

design may not be possible with pleated filters or other standard filtering media configurations. In addition, specific shapes or filter profiles may be required which may not easily be achieved with prior art filters.

Many inline filters have radial flow wherein the gas or liquid enters a center  
5 chamber and flows radially outward to a radially directed outlet. The changes in direction affect the fluid flow and lead to greater pressure differential across the filter. The inlet and outlet do not provide for straight through inline flow, often leading to additional ductwork and further upstream or downstream flow directional changes.

It can be appreciated that the automobile air filter has evolved significantly.  
10 The first filters had oil applied to the filter media for trapping particulate. Filter configuration changed to a pleated filter in an annular configuration positioned on top of the engine as filter technology improved. Filters in present automobiles typically utilize a panel-type filter configured to fit into the crowded spaces of smaller engine compartments. However, it can be appreciated that more efficient and smaller filters  
15 are needed with current and future vehicle designs.

Automobile engine air filters present special filtering problems. As automobile technology changes, greater emphasis is placed on improved passenger compartment room, while giving less space for the engine and related components. For example, recent cab forward designs move the passenger compartment forward and require  
20 transverse mounting of the engine with limited space for elements such as filters and related duct work. Smaller and smaller filters having the same or improved efficiency are needed to provide additional space for other components or for the passengers. In addition, semi-trucks and heavy-duty equipment often utilize air filters on the outside of the engine compartment and cab. For aerodynamics and appearance, as well as to  
25 improve visibility for the drivers and operators, manufacturers are moving the exterior filters into the engine compartment or under the hood, thereby adding to the space required.

Automobile manufacturers are attempting to achieve greater intervals between service. Many new models hope to delay servicing until 100,000 miles of use. It is  
30 preferred that the air filters utilized also be able to accept higher loading and be able to comply with the longer service intervals before replacement.

In addition to the more difficult space requirements and the life requirements of filters, greater performance is also being demanded from the air filters. Higher performance engines trying to achieve improved fuel efficiency often require much greater air flow rates. Such flows are achieved while trying to minimize the restriction at the filter. In addition, popularity of off-road vehicles with performance required in extremely harsh operating conditions requires improved filtering efficiencies while also requiring greater loading capacity so that filters do not need to be replaced at shortened intervals. The engine designs also require flexibility in filtering configurations so that the filter may adapt to the particular engine and vehicle model which are being produced.

A prior art filter which attempts to overcome these problems is shown in U.S. Patent 2,019,186 to Kaiser. Although the Kaiser patent shows corrugated type filtering media, it must be dipped in oil or other substance which cause particulate to adhere to the filter material. U.S. Patent 4,310,419 to Nara et al. provides greater filter density, but requires radial flow. U.S. Patent 4,289,513 shows corrugated or fluted filters, but provides only open flutes so that fluid may not actually pass through the filter media. U.S. patent 4,065,341 shows a method of making a spiral fluted filter, but the filter requires radial flow through the filter media.

It can be seen then that a new and improved filtering apparatus is needed. In particular, such a filtering apparatus should be structurally self-supporting to reduce support required from the filter housing. In addition, such an apparatus should provide increased filter media area for a given volume, thereby decreasing the pressure drop across the filter and the total volume required for the filter. The filter should provide for straight through flow rather than radial flow. Such a filter should also adapt to a variety of shapes and configurations and be easily inserted or removed from the flow. The present invention addresses these, as well as other problems associated with filtering apparatuses.

### Summary of the Invention

The present invention is directed to a filter apparatus and in particular, to a fluted filter apparatus which inserts inline into a duct and has substantially straight-through flow. According to the present invention, permeable fluted filter media is

utilized to provide a structurally self-supporting filter element. The fluted filter element includes planar layers or spirally-wound layers of fluted filter material having a corrugated layer and a facing sheet applied to one side with a beaded first end. The bead is then applied over the other side of the corrugated layer and the layer is pressed  
5 against an adjacent sheet to form a fluted filter layer having a series of adjacent flute chambers with alternating sealed ends. Therefore, flow through the upstream end enters the open fluted chambers and passes through the filtering media to the flute chambers having their downstream ends open, thereby filtering the fluid.

According to a first embodiment of the present invention, a filter element is  
10 placed in a housing which has a diameter which is enlarged relative to the upstream and downstream duct. In this manner, a larger filter media area is provided with a substantially smaller volume. Moreover, flow restrictions and pressure drop across the filter are decreased.

Alternate embodiments of the present invention provide for a variety of shapes  
15 and may also include a prefilter material upstream or around the filter element. Filter element shapes include cylinders, blocks, V-shaped elements, and oval-faced filter elements. Housings may be a simple seal downstream of the filter element or a housing including an inlet and outlet. The various embodiments provide for substantially straight-through flow wherein the upstream and downstream flow  
20 directions are substantially unchanged. It can be appreciated that the present invention provides for adapting to a wide variety of filtering shapes and passages.

These and various other advantages and features of novelty which characterize the invention are pointed out with particularity in the claims annexed hereto and forming a part hereof. However, for a better understanding of the invention, its  
25 advantages, and the objects obtained by its use, reference should be made to the drawings which form a further part hereof, and to the accompanying descriptive matter, in which there is illustrated and described a preferred embodiment of the invention.

30

### **Brief Description of the Drawings**

In the drawings, wherein like reference letters and numerals designate corresponding elements throughout the several views:

Figure 1 shows a perspective view of double-faced fluted filter media for the filter apparatus according to the principles of the present invention;

Figure 2A-2B show diagrammatic views of the process of manufacturing the filter media shown in Figure 1;

5 Figure 3 shows a perspective view of the fluted filter media layered in a block configuration according to the principles of the present invention;

Figure 4 shows a detail perspective view of a layer of single-faced filter media for the filter element shown in Figure 3;

10 Figure 5 shows a perspective view of the fluted filter media spiraled in a cylindrical configuration according to the principles of the present invention;

Figure 6 shows a detail perspective view of a portion of the spiraled fluted filter media for the filter element shown in Figure 5;

15 Figure 7 shows a side elevational partially broken away view of a first embodiment of a filter apparatus according to the principles of the present invention, having an enlarged diameter cylindrical fluted filter element and snap together housing placed in a duct;

20 Figure 8 shows a side elevational partially broken away view of a second embodiment of a filter apparatus according to the principles of the present invention, having an enlarged diameter cylindrical fluted filter element and buckled housing placed in a duct;

Figure 9 shows an exploded perspective view of a cylindrical type filter apparatus with a second filtering material mounted therearound according to the principles of the present invention;

25 Figure 10 shows an exploded perspective view of a cylindrical type filter apparatus according to the principles of the present invention;

Figure 11 shows an exploded perspective view of a block type filter apparatus according to the principles of the present invention;

Figure 12 shows an exploded perspective view of a V-block type filter apparatus according to the principles of the present invention;

30 Figures 13A, 13B, and 13C show a front elevational, top plan, and right side partial views of a prior art filter housing configured for accepting a panel filter element;

Figures 14A, 14B, and 14C show perspective views of a oval filter and housing according to the principles of the present invention;

Figure 15 shows a graph comparing pressure drop versus dust loading for the fluted filter media and standard filter media shown in Figures 13 and 14;

5        Figure 16 shows a sectional view of a second embodiment of fluted filter media with a filter inlet variation;

Figure 17 shows an exploded perspective view of a filter housing, a panel filter element and a prefilter layer;

Figure 18 shows a bottom plan view of the filter element shown in Figure 17;

10       Figure 19 shows a perspective view of the filter element shown in Figure 17 with a prefilter element attached;

Figure 20 shows a side sectional view of the filter element shown in Figure 19;

Figure 21 shows a top plan view of the filter element shown in Figure 19;

15       Figure 22 shows a graph restriction across the filter versus dust loading for a standard filter element for the filter housing shown in Figure 17, the fluted filter element shown in Figure 17, and the fluted filter element with the prefilter layer shown in Figure 18;

Figure 23 shows a sectional view of layered fluted filter media taken transverse to the longitudinal direction of the flutes;

20       Figure 24 shows a perspective view of an alternate embodiment of a fluted filter element for the filter housing shown in Figure 17;

Figure 25 shows a perspective view of an alternate embodiment of a fluted filter element for the filter housing shown in Figure 17; and,

25       Figure 26 shows a perspective view of an alternate embodiment of a fluted filter element for the filter housing shown in Figure 17.

#### Detailed Description of the Preferred Embodiment

Referring now to the drawings, and in particular to Figure 1, there is shown a portion of a layer of double-faced permeable fluted filter media, generally designated  
30    22. The fluted filter media 22 includes a multiplicity of flutes 24 which form a modified corrugated-type material. The flute chambers 24 are formed by a center fluting sheet 30 forming alternating peaks 26 and troughs 28 mounting between facing



5 sheets 32, including a first facing sheet 32A and a second facing sheet 32B. The troughs 28 and peaks 26 divide the flutes into an upper row and lower row. In the configuration shown in Figure 1, the upper flutes form flute chambers 36 closed at the downstream end, while upstream closed end flutes 34 are the lower row of flute chambers. The fluted chambers 34 are closed by first end bead 38 filling a portion of the upstream end of the flute between the fluting sheet 30 and the second facing sheet 32B. Similarly, a second end bead 40 closes the downstream end of alternating flutes 36. Adhesive tacks 42 connect the peaks 26 and troughs 28 of the flutes 24 to the facing sheets 32A and 32B. In a preferred embodiment, the adhesive of the tacks 42 is placed only at the apexes of the peaks 26 and troughs 28, rather than as a continuous bead, as shown in Figure 23. The minimal amount of adhesive keeps the chambers 24 of the flutes open to accept increased fluid flow. The flutes 24 and end beads 38 and 40 provide a filter element which is structurally self-supporting without a housing.

15 When filtering, unfiltered fluid enters the flute chambers 36 which have their upstream ends open as indicated by the shaded arrows. Upon entering the flute chambers 36, the unfiltered fluid flow is closed off by the second end bead 40. Therefore, the fluid is forced to proceed through the fluting sheet 30 or face sheets 32. As the unfiltered fluid passes through the fluting sheet 30 or face sheets 32, the fluid is filtered through the filter media layers, as indicated by the unshaded arrow. The fluid is then free to pass through the flute chambers 34, which have their upstream end closed and to flow out the downstream end out the filter media 22. With the configuration shown, the unfiltered fluid can filter through the fluted sheet 30, the upper facing sheet 32A or lower facing sheet 32B, and into a flute chamber 34 blocked on its upstream side.

25 Referring now to Figure 16, there is shown a second embodiment of the present invention with fluted filter media 222. The fluted filter media 222 is similar to the fluted filter media 22, shown in Figure 1, but having a modified bead configuration, as explained hereinafter. As shown in Figure 16, fluted filter media 222 includes flutes 224 having peaks and troughs with flutes 234 closed upstream and flutes 236 closed downstream. However, unlike other fluted filters, the flutes 234 include a bead 238 sealing off the flute chamber which is recessed from the upstream

30

WO 97/40917

PCT/US97/06612

8

edge of the filter media 222. The flutes 236 have beads 240 which are at the downstream end and may or may not be recessed away from the downstream edge.

The filter media 222 provides performance advantages as it can be appreciated that large particles may accumulate at the upstream face of the filter media. As shown in Figure 16, if the particles 1000 are large enough, some of the flutes 224 may become completely blocked off. For prior filter media, if several flutes are blocked off, the blockage 1000 has greater impact as alternating surrounding flutes are blocked at their upstream side, creating increased flow redirection around the blocked flutes. However, as shown in Figure 16, when flutes 234 are sealed at their upstream side at 238 and recessed from the upstream edge, when a particle 1000 blocks an adjacent downstream closed flute 236, the configuration allows the flow to pass into the upstream end of the flutes 234 and through the fluting sheet 230 or other filter material upstream of the seal 238. In this manner, the fluid flows into flute 236 where it is forced back through the filtering material into the flutes 234 which are open to the downstream side of the filter. This reduces clogging and provides for better flow without pressure buildup or otherwise adversely affecting filter performance. In a preferred embodiment, the upstream sealing beads 238 are recessed from approximately 1/4" to 1" from the upstream edge. In this manner, the fluted material is still self supporting while decreasing the effects of clogging at the upstream face of the filter media 222.

Referring now to Figures 2A-2B, the manufacturing process for fluted filter media which may be stacked or rolled to form filter elements, as explained hereinafter, is shown. It can be appreciated that when the filter media is layered or spiraled, with adjacent layers contacting one another, only one facing sheet 32 is required as it can serve as the top for one fluted layer and the bottom sheet for another fluted layer. Therefore, it can be appreciated that the fluted sheet 30 need be applied to only one facing sheet 32.

As shown in Figure 2A, a first filtering media sheet 30 is delivered from a series of rollers to opposed crimping rollers 44 forming a nip. The rollers 44 have intermeshing wavy surfaces to crimp the first sheet 30 as it is pinched between the rollers 44 and 45. As shown in Figure 2B, the first now corrugated sheet 30, and a second flat sheet of filter media 32 are fed together to a second nip formed between the

first of the crimping rollers 44 and an opposed roller 45. A sealant applicator 47 applies a sealant 46 along the upper surface of the second sheet 32 prior to engagement between the crimping roller 44 and the opposed roller 45. At the beginning of a manufacturing run, as the first sheet 30 and second sheet 32 pass through the rollers 44 and 45, the sheets fall away. However as sealant 46 is applied, the sealant 46 forms first end bead 38 between the fluted sheet 30 and the facing sheet 32. The troughs 28 have tacking beads 42 applied at spaced intervals along their apex or are otherwise attached to the facing sheet 32 to form flute chambers 34. The resultant structure of the facing sheet 32 sealed at one edge to the fluted sheet 30 is single-faced layerable filter media 48, shown in Figure 4.

Referring now to Figure 3, it can be appreciated that the single-faced filter media layer 48 having a single backing sheet 32 and a single end bead 38 can be layered to form a block-type filter element, generally designated 50. It can be appreciated that a second bead 40 is laid down on an opposite edge outside of the flutes so that adjacent layers 48 can be added to the block 50. In this manner, first end beads 38 are laid down between the top of the facing sheet and the bottom of the fluted sheet 30, as shown in Figure 4, while the space between the top of the fluting sheet 30 and the bottom of the facing sheet 32 receives a second bead 40. In addition, the peaks 26 are tacked to the bottom of the facing sheet 32 to form flutes 36. In this manner, a block of fluted filter media 50 is achieved utilizing the fluted layers 48 shown in Figure 4. The filter element 50 includes adjacent flutes having alternating first closed ends and second closed ends to provide for substantially straight-through flow of the fluid between the upstream flow and the downstream flow.

Turning now to Figures 5 and 6, it can be appreciated that the single-faced filter media 48 shown in Figure 4 can be spiraled to form a cylindrical filtering element 52. The cylindrical filter element 52 is wound about a center mandrel 54 or other element to provide a mounting member for winding, which may be removable or left to plug the center. It can be appreciated that non-round center winding members may be utilized for making other filtering element shapes, such as filter elements having an oblong or oval profile. In addition, the filter elements may be selectively compressed prior to the sealant material hardening for shaping the elements. As a first bead 38, as shown in Figure 4, has already been laid down on the filter media layer 48,

WO 97/40917

PCT/US97/06612

10

it is necessary to lay down a second bead 40 with the sealing device 47, shown in Figure 5, at a second end on top of the fluted layer 30. Therefore, the facing sheet 32 acts as both an inner facing sheet and exterior facing sheet, as shown in detail in Figure 6. In this manner, a single facing sheet 32 wound in layers is all that is needed  
5 for forming a cylindrical fluted filtering element 52. It can be appreciated that the outside periphery of the filter element 52 must be closed to prevent the spiral from unwinding and to provide an element sealable against a housing or duct. Although in the embodiment shown, the single faced filter media layers 48 are wound with the flat sheet 32 on the outside, there may be applications wherein the flat sheet 32 is wound  
10 on the inside of the corrugated sheet 30.

Referring now to Figure 7, there is shown a first embodiment of a spiral filter apparatus according to the principles of the present invention, and generally designated 60. The filter apparatus 60 inserts into a duct 64 connecting to a housing 62. The filter housing 62 has a substantially widened diameter relative to the duct for  
15 receiving a cylindrical filter element 52 having a larger flow receiving face than the cross-sectional area of the duct 64. The filter housing 62 includes a skin or other outer protective layer or housing portion 66 and transitional portions 68 which flare outward from the diameter of the duct to the enlarged diameter outer housing layer 66. The housing 62 connects to the duct through plastic clip-type connectors 70 which snap the  
20 transitional portions 68 of the filter housing 62 to the duct 64. In addition, gaskets 71 provide a seal between the housing 62 and the duct 64 while clips 72 retain the transitional members 68 to the outer protective layer 66 of the filter 60. This provides quick and easy connection so that the transitional members 68 may be inserted and connected to the duct 64 and the filter housing 62. Gaskets 73 provide an air and/or  
25 liquid-tight seal between the outer portion 66 of the filter housing 62 and the transitional members of the housing 68. In this manner, the housing 62 serves as a portion of the duct 64.

It can be appreciated that although the outer housing portion 66 may be a structurally-supportive member such as plastic or other commonly used materials, it  
30 may also be just the sealed impermeable outer layer of the filter element 52. The outer housing portion 66 may be separate or integral with the filter element 52. It can be appreciated that the outer layer 66 must seal the filter element 52 so that filtered fluid

WO 97/40917

PCT/US97/06612

11

does not escape to the exterior of the closed passage formed by the duct 64 and the filter 60. However, the fluted filter media is structurally self-supporting so that no additional structure may be required on the periphery of the filter element 52 for some filtering applications. It can also be appreciated that the clip and gasket arrangements of the embodiment shown provide for a quick and easy replacement and interchangeability of the filter elements 52 in the duct. The filter 60 placed in this position provides for substantially straight-through flow with relatively low pressure drop across the filter 60 and increased filter media area for the volume of filter.

Referring now to Figure 8, there is shown a second embodiment of an inline filter apparatus having a housing, generally designated 74. The second embodiment again includes a cylindrical-type filter element 52 inserting into a duct 64. The filter 74 has transitional members 68 and an outer filter housing portion 66. Clips 70 attach the housing 66 to the duct 64 and use gaskets 71 to form a seal between the housing 66 and the duct 64. However, the attachment between the filter element 52 and the transitional member 68 of the housing utilizes bands 76 extending around the filter 74 which have a plurality of tabs that clip on to the transitional members 68 and the exterior housing portion 66. Each of the bands 76 has a buckle 78 which can be tightened to provide a seal around gasket 73. The embodiment shown in Figure 8 provides for quick and easy removal and interchangeability of the filter element 52. In addition, the filter 74 provides for substantially straight-through flow from the upstream to the downstream side of the duct 64.

Referring now to Figure 9, there is shown a further embodiment of the present invention, generally designated 84. According to the embodiment shown, a spiral filter element 52 is surrounded by non-permeable filler material 86, such as a solid urethane or other inexpensive lightweight impermeable material. The non-permeable filler material 86 is wrapped around the filter element 52 to fit within the sections of the housing 88 and provides for configuring the filter element to a wide variety of housing and/or duct shapes.

For the embodiment shown in Figure 10, a filter, generally designated 90, has a spiral filter element 52 which is preceded by a prefilter of open material, generally designated 94. A product suitable for the prefilter layer 94 is sold under the tradename Airlaid Media by Comulus Fiber Corp. located in Charlotte, N.C. For a thickness of

0.75", the open material has a density of 6.7 ounces/yd<sup>2</sup> and a solidity of 0.8%. Another suitable prefilter material having a thickness of 0.25" with a density of 3.62 ounces/yd<sup>2</sup> and a solidity of 1.6% is available from Chemwove Corp. in Charlotte, N.C. The prefiltering material 94 removes the larger particles and other contaminants prior to filtering through the fluted filter element 52. The filter element 90 may also include an outer housing 92, and if the center mandrel has been removed, center caps 96 extend through the center of the spiral filter element 52. An O-ring or other gasket 98 may be placed on the downstream side of the filter 94, providing a seal downstream to prevent escape of the filtered fluid and inlet of unfiltered fluids.

Yet another embodiment of the present invention is shown in Figure 11. Block filter 100 utilizes a block-filter element 50 and includes a housing 102 extending on the ends, top and bottom of the filter element 50. A gasket 102 is placed on the periphery of the block filter 100 on the downstream side to form a seal between the duct or other passage and the filter 100.

Referring now to Figure 12, there is shown yet another embodiment of the present invention utilizing a V-type filter, generally designated 110. The V-type filter utilizes a pair of block filter elements 50 which are arranged with one end in proximity and the second end diverging from the first end. Top and bottom spacing members 114 of the filter housing 112, as well as an end spacing member 116 retain the block filter elements 50 in their relative positions. With this configuration, flow enters both sides of the housing 112 and passes through the center orifice of the end spacing member 116. A gasket 118 provides a downstream seal to the housing 112. With this arrangement, the filter elements 50 may be cleaned with reverse air pulsing.

Referring to Figures 13A-13C, there is shown a prior art filter and housing, generally designated 120, utilized in an automobile engine. The filter housing includes an inlet 122 and an outlet 124. Housing sections 126 and 128 fit together to form a sealed filter chamber. The housing 120 is configured to form a substantially rectangular interior chamber, as most clearly shown in Figure 13B, for receiving a panel filter element 125.

Shown in Figures 14A-14C is an oval filter, generally designated 130 which is suitable for replacing the prior art filter shown in Figures 13A-C. The oval filter 130 includes a housing 132 surrounding an oval profile fluted filtering element 134. As

explained above, the housing 132 may just be a sealed impermeable exterior of the oval element 134 or a separate exterior housing member. In addition, the filter 130 includes an inlet element 136 and outlet element 138. These elements are clasped to the filter housing 132 by connector bands 140. In this manner, the filter element 134  
5 may be easily removed and replaced by loosening and removing the bands and reinserting a new filter element 134. It can be appreciated that although an oval element is shown, other filter elements having different cross sections could also be utilized.

It can be appreciated that the filter elements of the present invention provide  
10 for greater filter media area in a much smaller housing volume than the prior art. For the panel filter shown in Figure 13, the housing volume is  $0.27 \text{ ft}^3$  and the filter media area is only  $6.6 \text{ ft}^2$ . However, for the fluted filter shown in Figure 14, having a 9 inch long filter and a similar  $0.27 \text{ ft}^3$  of filter housing volume, the filter has  $35 \text{ ft}^2$  of filter media area. A similar 5" long fluted filter has a filter housing volume of  $0.20 \text{ ft}^3$ , but  
15 still has a filter media area of  $21 \text{ ft}^2$ . It can also be appreciated that the present invention provides for placing a filter element inline into a duct which typically is only slightly widened at the filter with a portion of the duct serving as the filter housing.

Referring now to Figure 15, there is shown a graph comparing restriction across the filter to the amount of material deposited on the filter for the filters shown in  
20 Figures 13 and 14. It can be appreciated that as the filter loads, the restriction across the filter increases. However, it can be appreciated that although there is a gradual rise for fluted filters of the present invention, the restriction increases exponentially for the panel filter element shown in Figure 13. Therefore, standard filters must be replaced after a much shorter interval and the design of the system may need to be adjusted to  
25 accommodate the increased restriction. Alternatively, the increased restriction may cause additional damage or require other design alterations to accommodate the increased restriction. It is generally recommended that air filters used with automobiles are replaced when the restriction rises above 14" of water. It can be appreciated that the panel filter shown in Figure 13 requires replacement before 200  
30 gms are loaded, while the fluted filter according to the principles of the present invention shown in Figure 14 will not require replacement until over 800 gms are loaded.

Referring now to Figures 17-21, there is shown an alternate embodiment of the filter element, generally designated 150. The filter element 150 mounts in a housing having two sections including a fluid inlet and an outlet. The housing also includes a center post which is used for positioning prior art panel-type pleated filters. The filter element 150 includes fluted filter media 152 connected to a positioning bracket portion 154. In addition, a center recessed cup-type aligning member 156 receives the post from the housing to maintain the filter 150 in the correct position. Although an oval filter media element is shown, it can be appreciated that other common shapes, as explained hereinafter, could also be utilized. The bracket 154 seats on a ridge in the housing and retains the filter element 150 in the correct position. In addition, a gasket 158 seats against the housing to form a seal to prevent fluid from bypassing the filter element 150. The filter media 152 is the fluted filter media described above and is typically coiled about the center recessed member 156. However, a square or rectangular block type element may also be utilized and the center cut out to accommodate the post.

As shown in Figures 19-21, in addition to the fluted filter element 152, a prefilter element 160 is placed over the upstream portion of the filter media 152. The prefilter element 160 includes a top portion 162 and side portions 164 which substantially cover the filter media 152 upstream from the bracket 154. The sides of the filter element 152 provide added filtering capacity. The prefilter element 160 includes sides 164 to further increase capacity. A band 170 fits around the exterior of the prefilter element 160 and retains it in position. The band 170 includes an outward curled edge proximate the bracket 154 to ease assembly and removal and to provide a better seal around the exterior of the prefilter element 160. The band 170 may be bonded or otherwise secured in some applications. In a preferred embodiment, the prefilter material is an open material, such as that described above and shown in Figure 10. However, other types of open materials which provide some prefilter and spacing to separate the ends of the flutes from possible large particles of debris that could clog flutes may also be utilized, such as reticulated foam. These open type materials may also be used wherein snow is present. The open porous structure of these materials absorbs the snow and acts to prevent the flutes of the filter element 162 from becoming plugged. It can be appreciated that the filter element 150 and the prefilter 160 may be



independently changed and replaced depending on the required service interval or each element.

In addition to the oval filter element 150 shown in Figure 17, filter elements having a different shaped profile may also be utilized. As shown in Figure 24, filter element 180 includes oval shaped filter media 182 coiled around an oval center member 184. As shown in Figure 25, filter element 186 includes round filter media 188. As shown in Figure 26, filter element 190 includes block type filter media 192. It can be appreciated that other shapes could also be utilized and that prefilter elements could be configured to mount to the filter media.

Referring now to Figure 22, there is shown a graph of restriction across the filter element as the filter element loads with dust and particulate. The graph is for a 5.9 liter diesel with the standard fan-type pleated filter being shown, as well as the restriction and dust loading for the filter element 150, and the filter element 150 having a prefilter 160 mounted thereon. It can be appreciated that 14 inches of restriction is the recommended change out, so that the pleated filter normally is changed before 200 grams of dust are loaded onto the filter. For the fluted filter element 150, changing is generally not required until almost 400 grams of dust are loaded onto the filter, or almost twice the capacity of a standard pleated filter. Even further improvement is shown when the prefilter material 160 is used on the filter element 150. Nearly 750 grams of dust are loaded before 14 inches of restriction is found across the filter element. Therefore, almost four times the capacity of the pleated filter is obtained when the fluted filter element 150 is utilized with a prefilter element 160.

It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the attached claims are expressed.

WO 97/40917

PCT/US97/06612

16

What is claimed is:

1. A filter device for inserting into a duct having flow passing from upstream to downstream through the filter, comprising:

5 structurally self-supporting filtering media having an outer portion;  
an impermeable layer enclosing the outer portion of the filter media; and,  
means for forming a seal between the impermeable layer and the duct on the downstream side of the filter media when the filter media is inserted into the duct.

10 2. A filter device according to claim 1, wherein the filter media comprises a plurality of substantially parallel flutes.

3. A filter device according to claim 1, wherein the filter includes an upstream face and a downstream face, and wherein the upstream face of the filter engaging the flow comprises a cross sectional flow approach area greater than the  
15 cross sectional area of the duct.

4. A filter device according to claim 1, further comprising sealing means extending between the duct and the impermeable layer and a tightening band engaging the sealing means.

20 5. A filter device according to claim 4, wherein the sealing means further comprises an annular gasket member.

6. A filter device according to claim 5, wherein the sealing means  
25 extending between the impermeable layer and the duct comprises an upstream seal and a downstream seal.

7. A filter device according to claim 1, wherein the filter is aligned  
30 relative to the upstream flow to provide substantially straight through flow from the duct through the filter.

8. A filter device for inserting into a duct having flow passing from upstream to downstream through the filter, comprising:

structurally self-supporting fluted filtering media having a plurality of substantially parallel flutes defining an outer portion, wherein the flutes are aligned relative to the upstream flow to provide substantially straight through flow through the filter device;

an impermeable protective layer enclosing the outer portion of the filter media; and,

means for forming a sealed connection to the protective layer on the downstream side of the filter media when the filter media is placed in the duct.

9. A filter device according to claim 8, wherein the filter media is configured in a substantially rectangular block configuration.

10. A filter device according to claim 8, wherein the filter media is configured in an oval configuration.

11. A filter device according to claim 8, further comprising prefiltering open material upstream of the fluted filter media.

12. A filter device according to claim 9, wherein the filter comprises a pair of filter blocks configured in a V-type configuration.

13. A filter according to claim 8, wherein the filtering media comprises alternating first and second flutes, wherein the first flutes include closed portions recessed from the upstream side and the second flutes include closed portions at the downstream side.

14. A method of making a filter having flow passing from upstream to downstream through the filter, comprising the steps of:

forming a length of fluted filter media having a first and second face; depositing a sealing material on at least one face; and,

WO 97/40917

PCT/US97/06612

18

layering the length of filter media to form a filter element such that adjacent layers of the filter media are sealed.

15. A method according to claim 14, wherein the layering step comprises  
5 rolling the filter media in a spiraling configuration, thereby sealing adjacent layers.

16. A method of making a filter according to claim 15, wherein the layering step includes rolling the filter media about a center member.

10 17. A method of making a filter according to claim 14, wherein the layering step comprises stacking the filter media in a block configuration.

18. A method of making a filter according to claim 14, comprising the further step of sealing an exterior of the layered filter media to a duct.

15

19. A method of making a filter according to claim 14, comprising the further step of sealing a periphery of the spiraled filter media to an outer protective layer.

20

20. A method of making a filter, comprising the steps of:

forming a length of fluted filter material having a first and second face and a first and second edge;

depositing a sealing material proximate the first edge on the first face of the filter media;

25

applying a facing sheet having a first side and a second side to the first face of the fluted filter material, thereby forming a seal between the fluted filter material and a first side of the facing sheet;

applying a sealing material proximate the second edge on the second face of the fluted filter material;

30

forming the length of fluted filter media in an overlapping configuration, thereby sealing the second face of the fluted filter material to the second side of an adjacent layer of the facing sheet.

21. A method according to claim 20, comprising the further step of applying adhesive tacks at spaced intervals to apexes of the fluted filter material.

5 22. A filter device for having flow passing from upstream to downstream through the filter, comprising:

structurally self-supporting filtering media having an outer portion;  
an impermeable layer enclosing the outer portion of the filter media; and,  
means for forming a seal between the impermeable layer and the duct on the  
10 downstream side of the filter media.

23. A filter device for having flow passing from upstream to downstream through the filter, comprising:

structurally self-supporting fluted filtering media having an outer portion;  
15 an impermeable layer enclosing the outer portion of the filter media; and,  
an open filter material intercepting flow upstream from the self-supporting filtering media.

24. A filter device according to claim 23, wherein the open filter material  
20 comprises an element having a base and side portions extending over an upstream face and upstream portions of sides of the filtering media.

25. A filter device according to claim 24, further comprising a band  
extending around a periphery of the open filter element.

25 26. A filter device according to claim 23, further comprising a bracket extending from sides of the filter media.

27. A filter device according to claim 23, wherein the outer filtering media  
30 comprises a filter element having an oval configuration.

WO 97/40917

PCT/US97/06612

20

28. A filter device according to claim 23, wherein the outer filtering media comprises a filter element having a round configuration.

29. A filter device according to claim 23, wherein the outer filtering media  
5 comprises a filter element having a substantially rectangular configuration.

30. A filter device according to claim 25, wherein the band includes an edge flaring outward.

10 31. A filter device according to claim 23, further comprising a bracket portion mounting to the periphery of the fluted filtering media.

32. A filter device according to claim 8, further comprising open material intermediate the filtering media and the impermeable protective layer.

15

33. A filter device according to claim 8, wherein the filter media is configured in a substantially cylindrical configuration.

20 34. A filter device for inserting into a duct having flow passing from upstream to downstream through the filter, comprising:

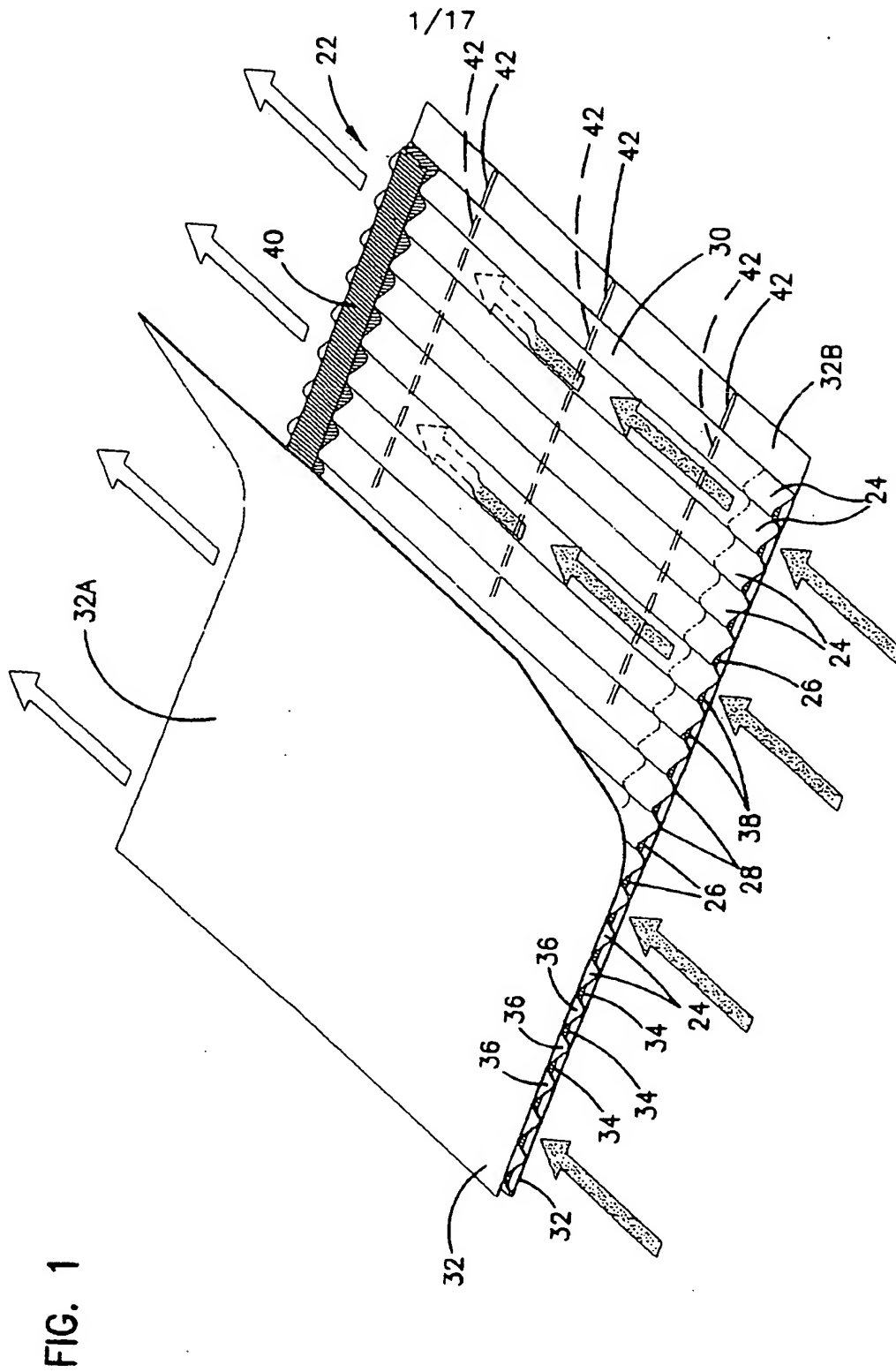
structurally self-supporting fluted filtering media having a plurality of substantially parallel flutes defining an outer portion, wherein the flutes are aligned relative to the upstream flow to provide substantially straight through flow through the filter device;

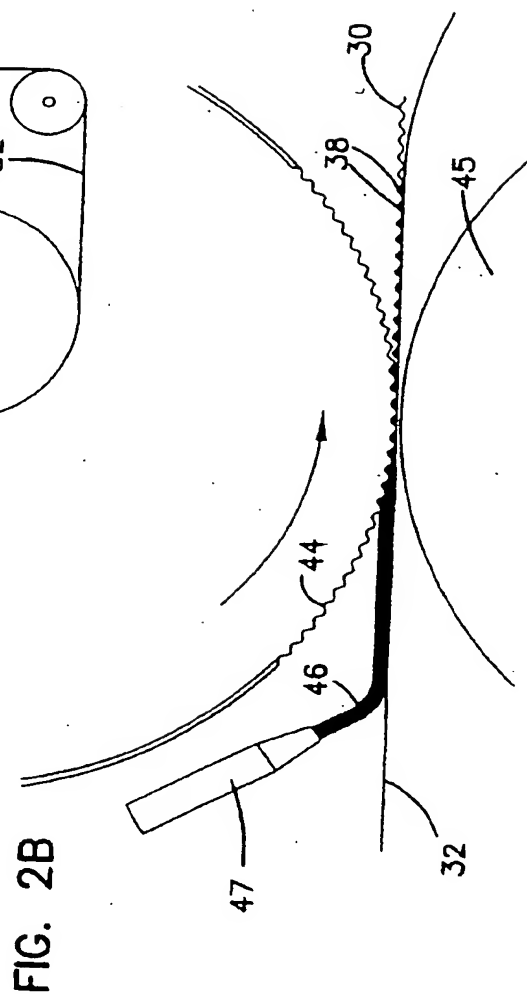
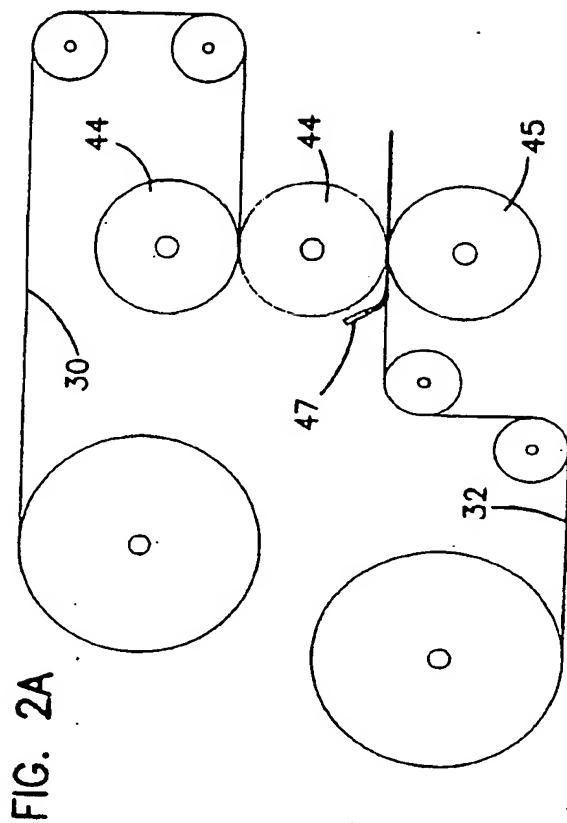
25 an impermeable protective layer enclosing the outer portion of the filter media; and,

means for closing the connection between the protective layer and the duct on the downstream side of the filter media when the filter media is placed in the duct.

WO 97/40917

PCT/US97/06612







3/17

FIG. 3

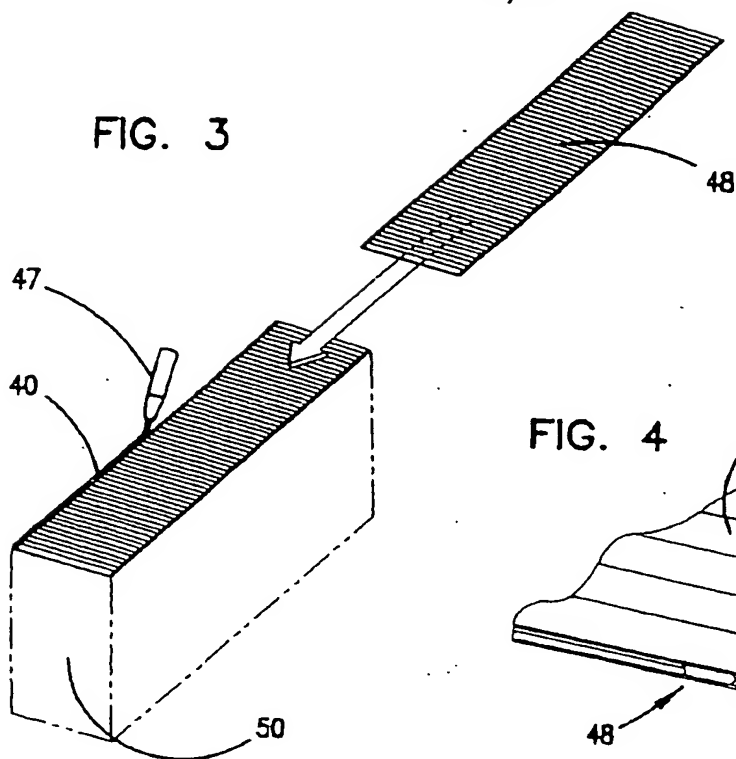


FIG. 4

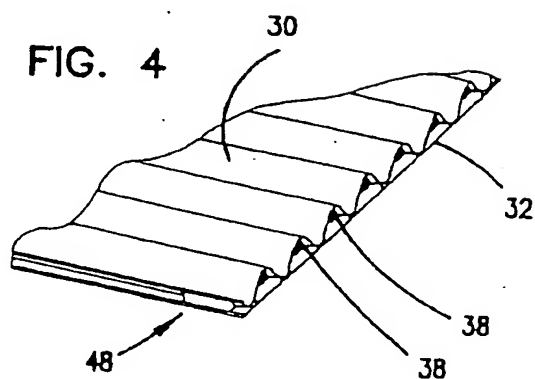


FIG. 5

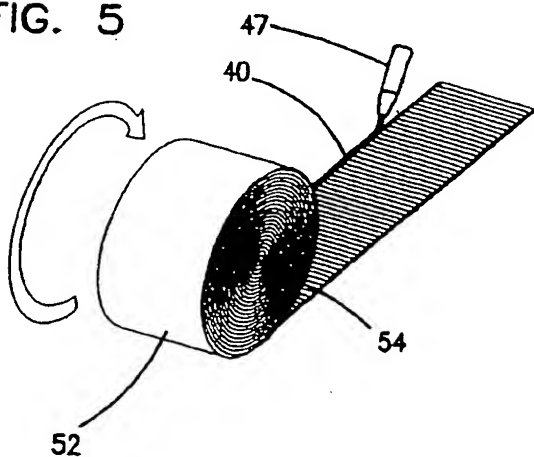
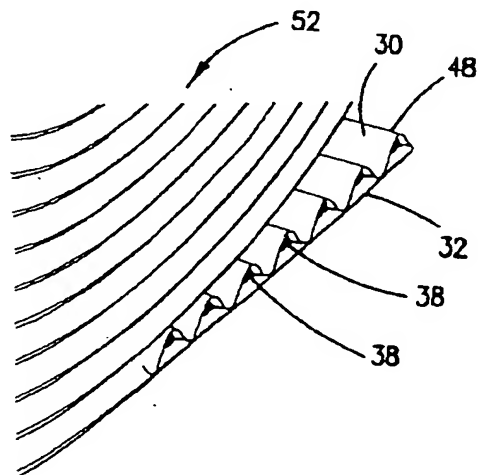


FIG. 6



WO 97/40917

PCT/US97/06612

4/17

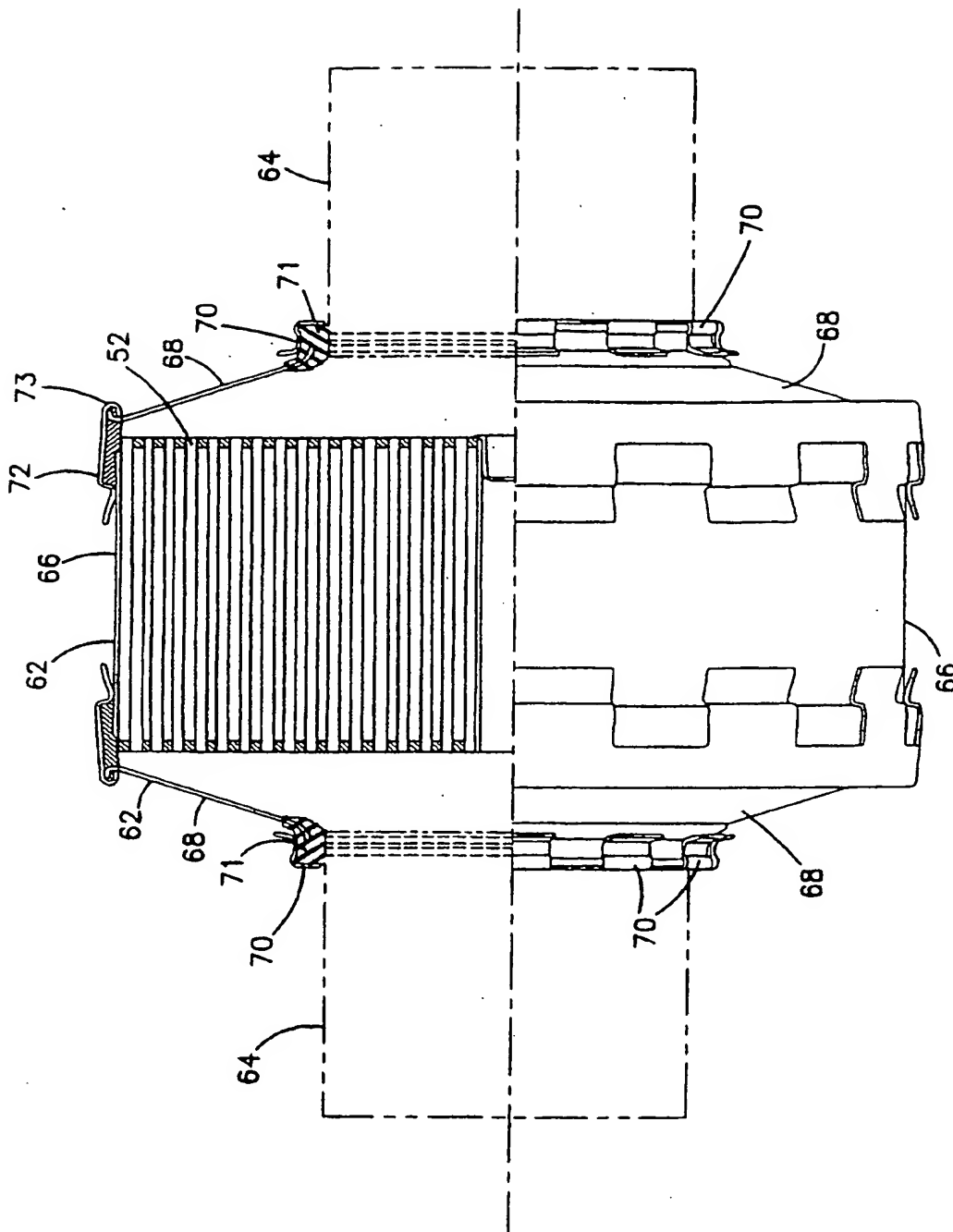
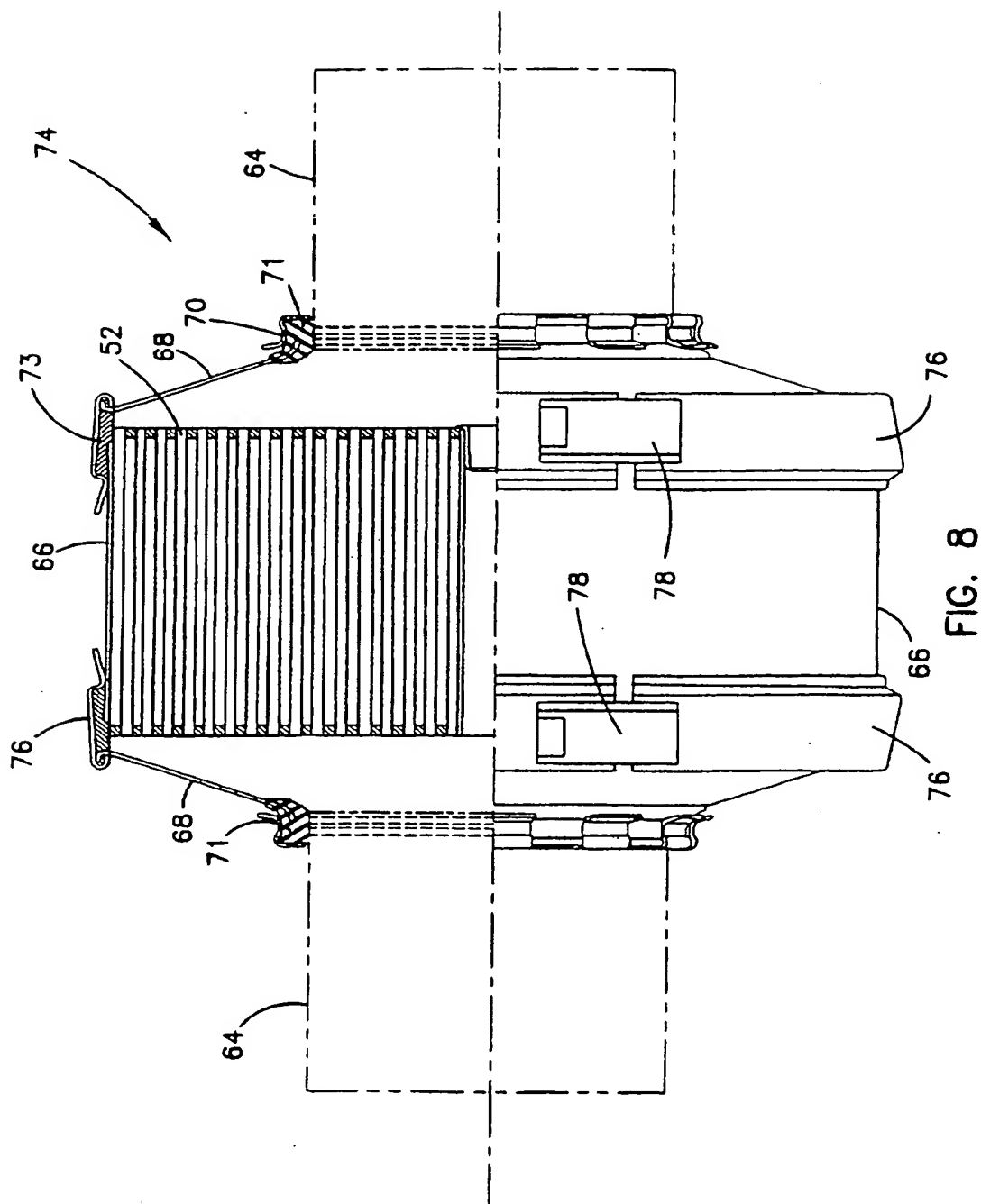


FIG. 7

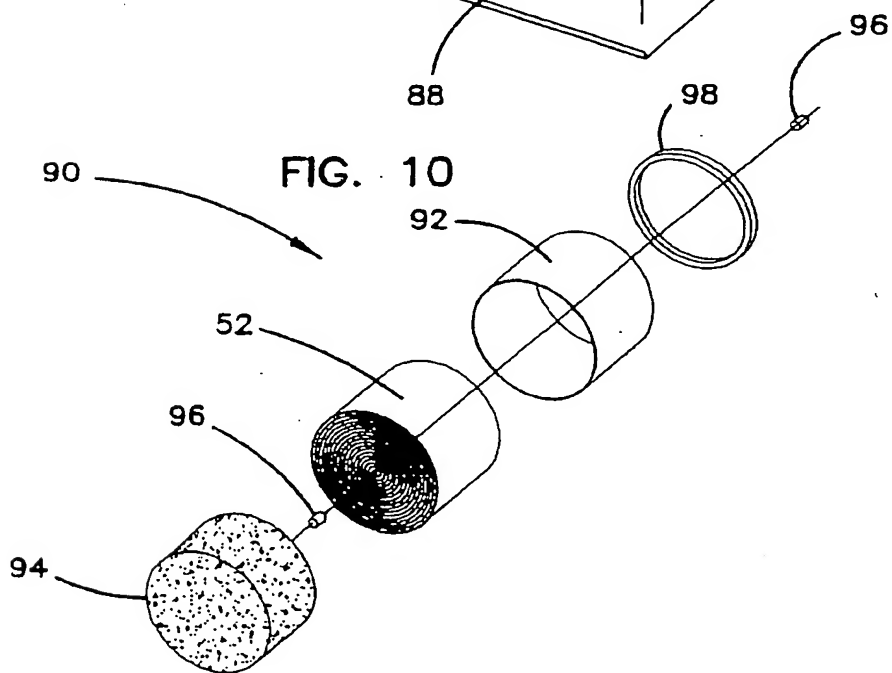
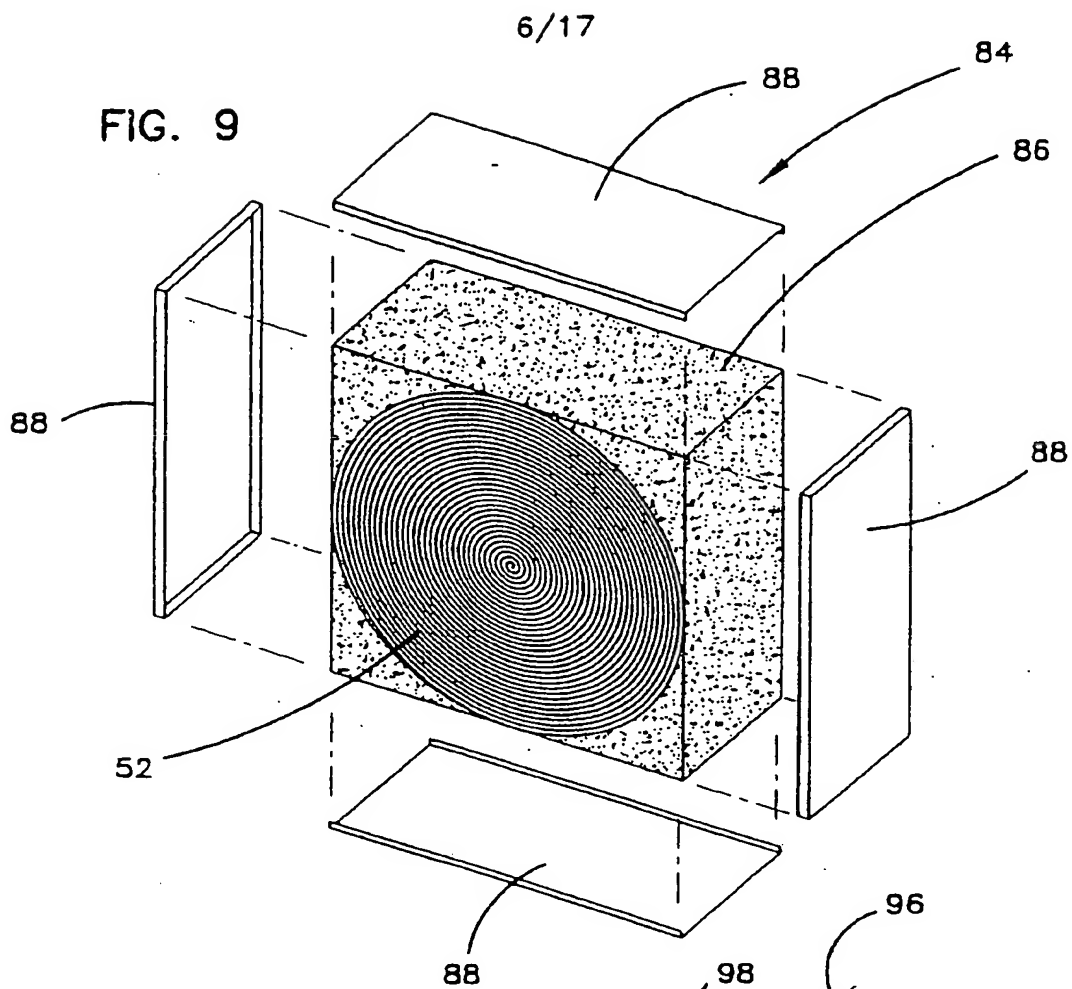
5/17



**SUBSTITUTE SHEET (RULE 26)**

WO 97/40917

PCT/US97/06612



SUBSTITUTE SHEET (RULE 26)

WO 97/40917

PCT/US97/06612

FIG. 11

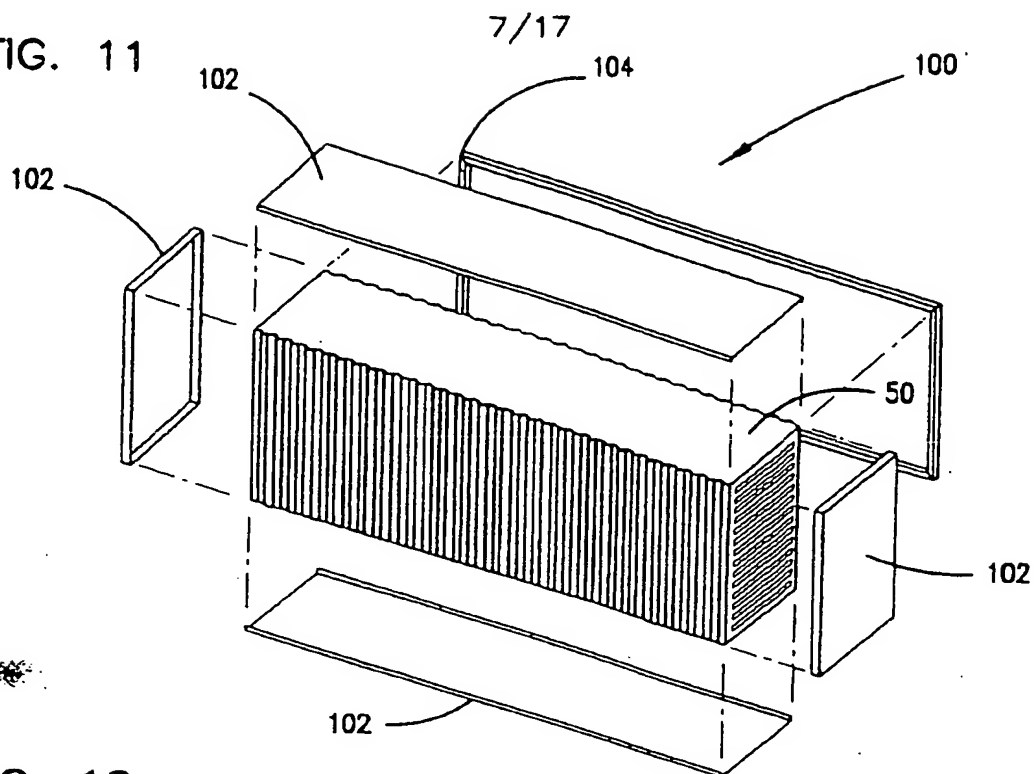
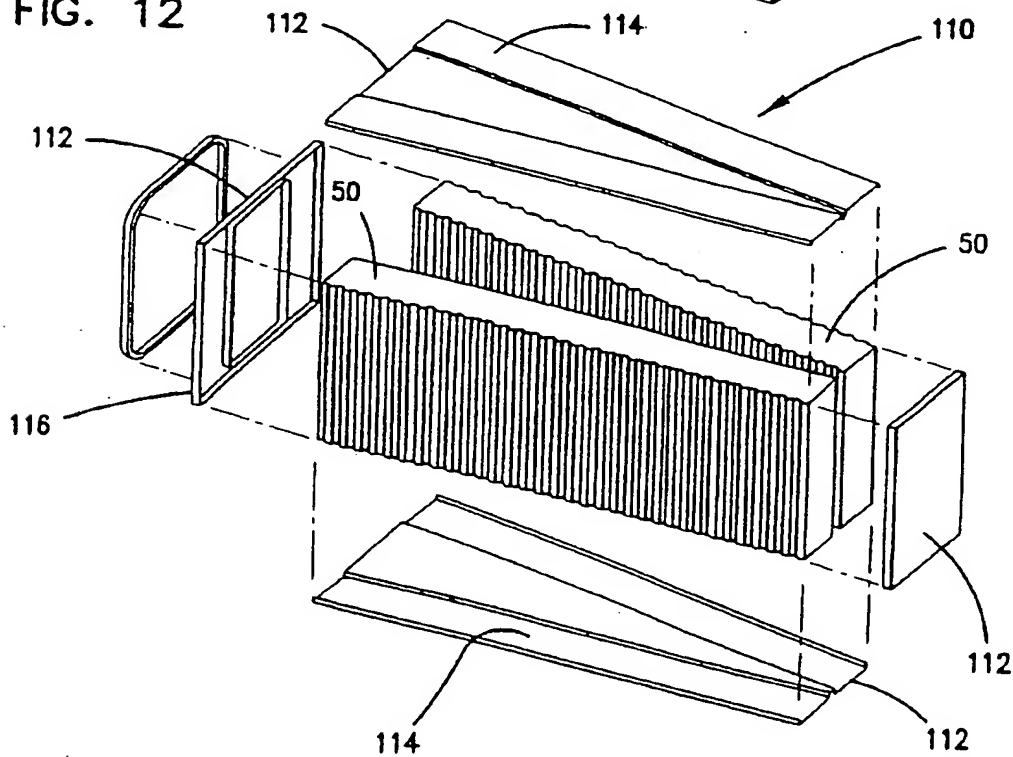
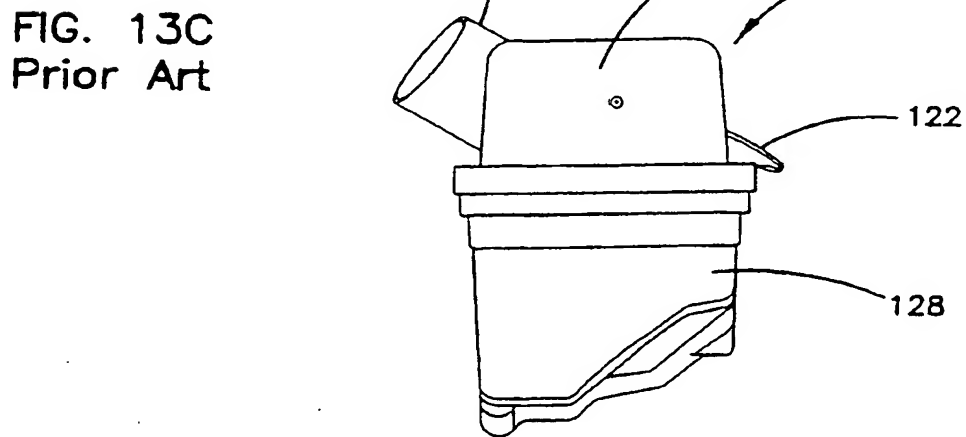
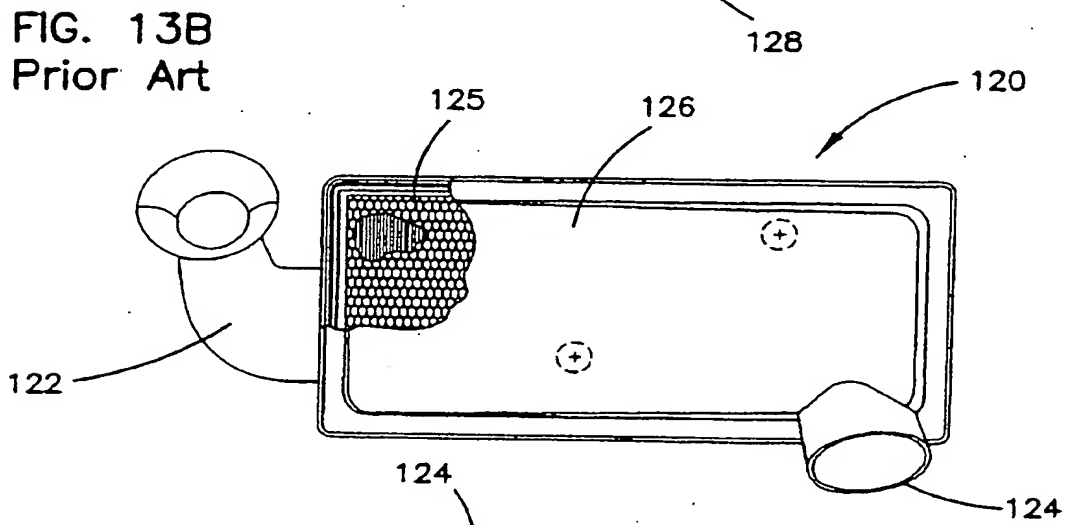
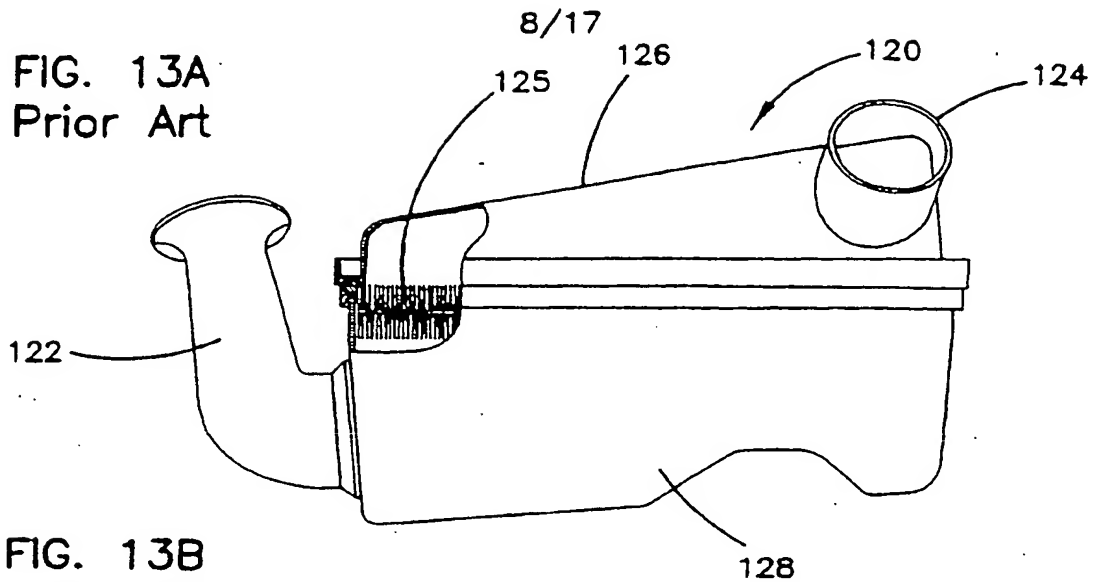


FIG. 12



WO 97/40917

PCT/US97/06612



WO 97/40917

PCT/US97/06612

9/17

FIG. 14A

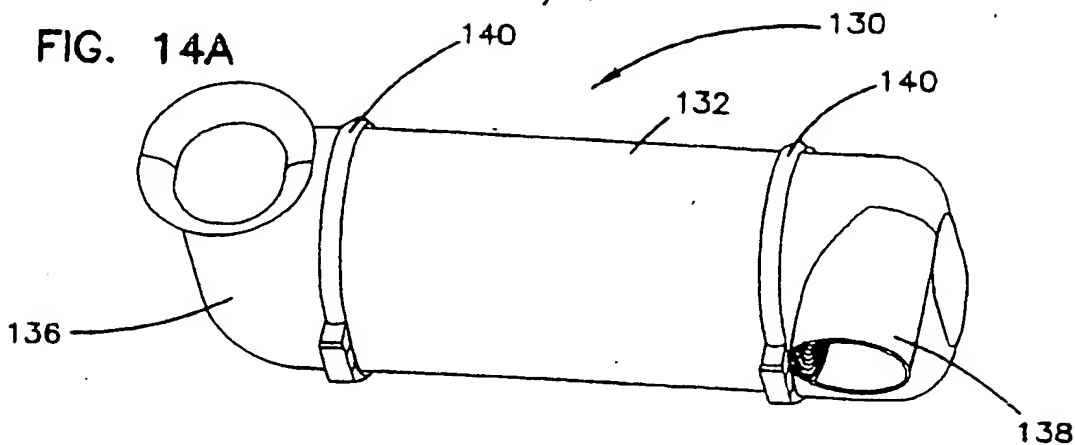


FIG. 14B

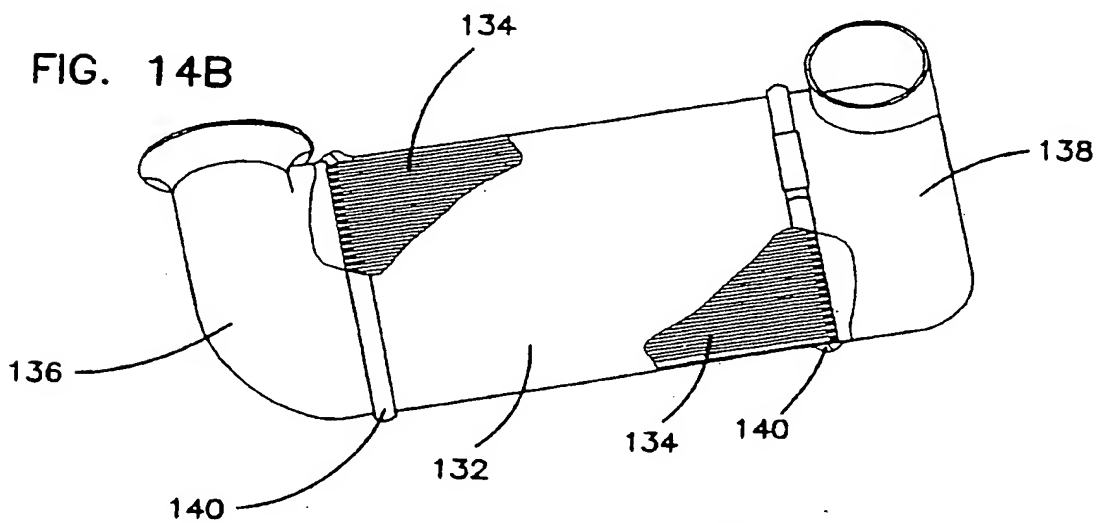
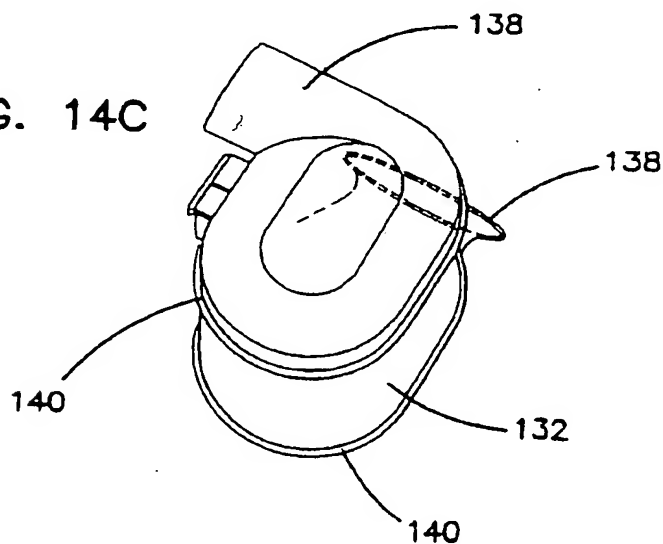


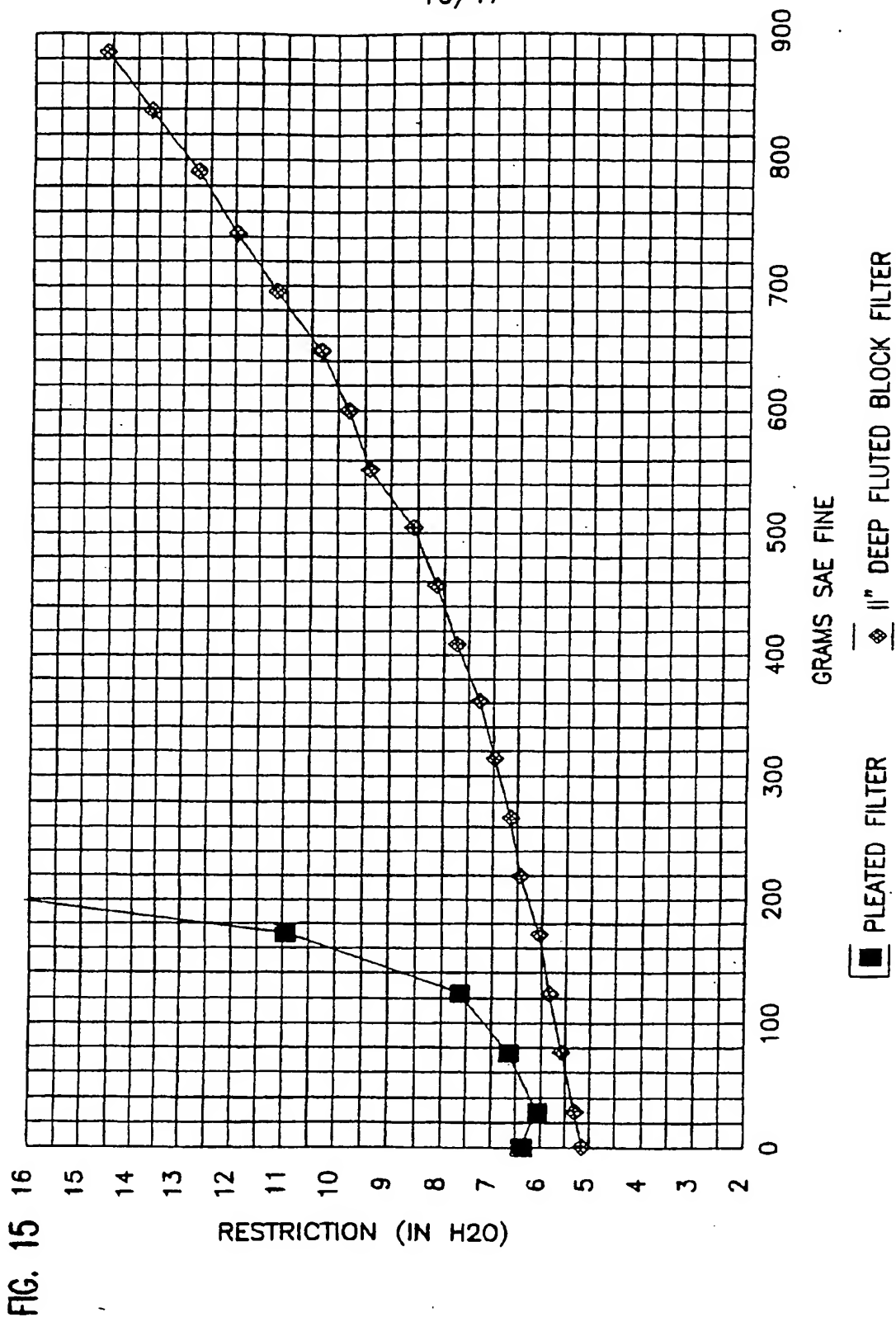
FIG. 14C



WO 97/40917

PCT/US97/06612

10/17





11/17

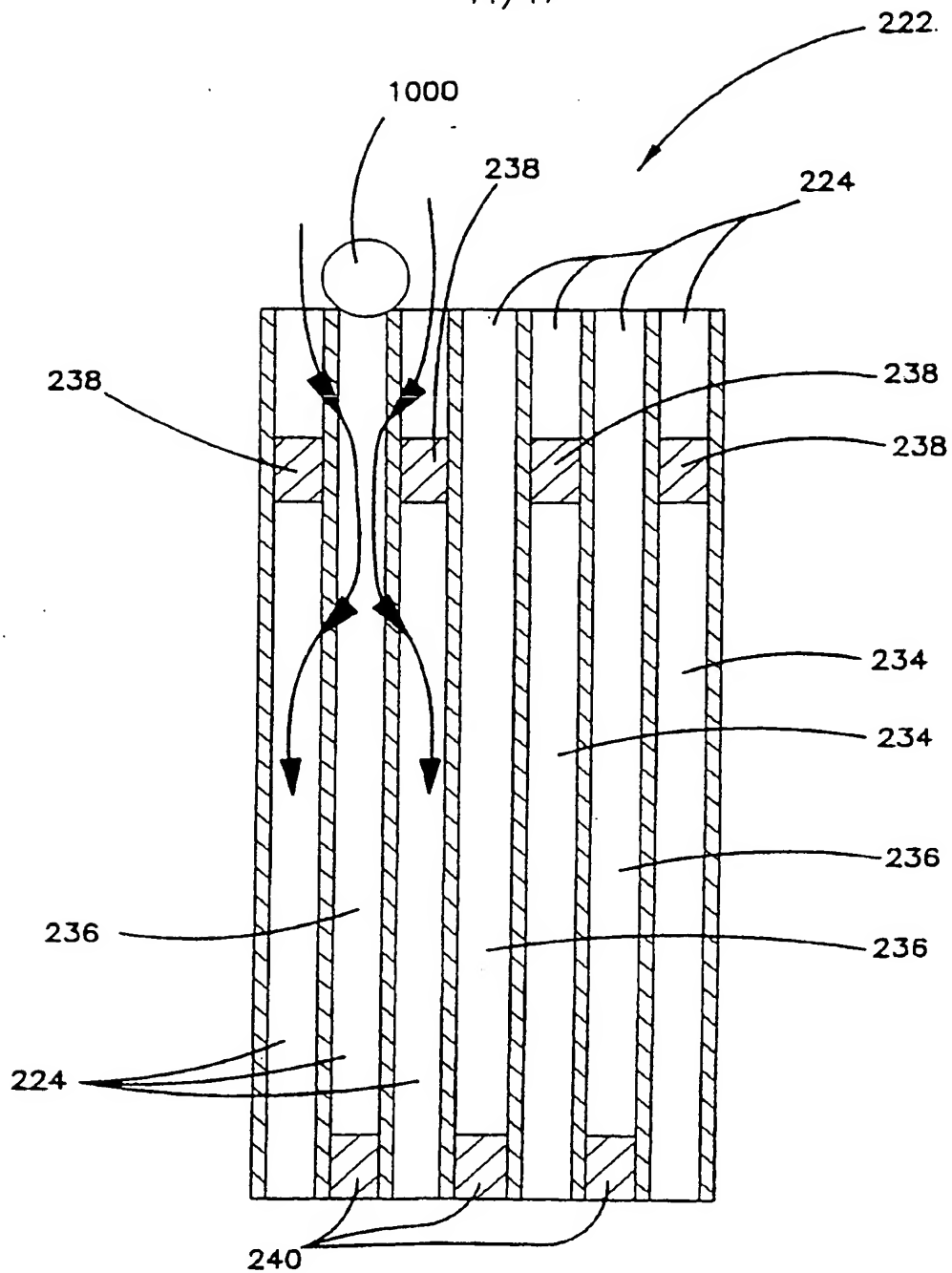
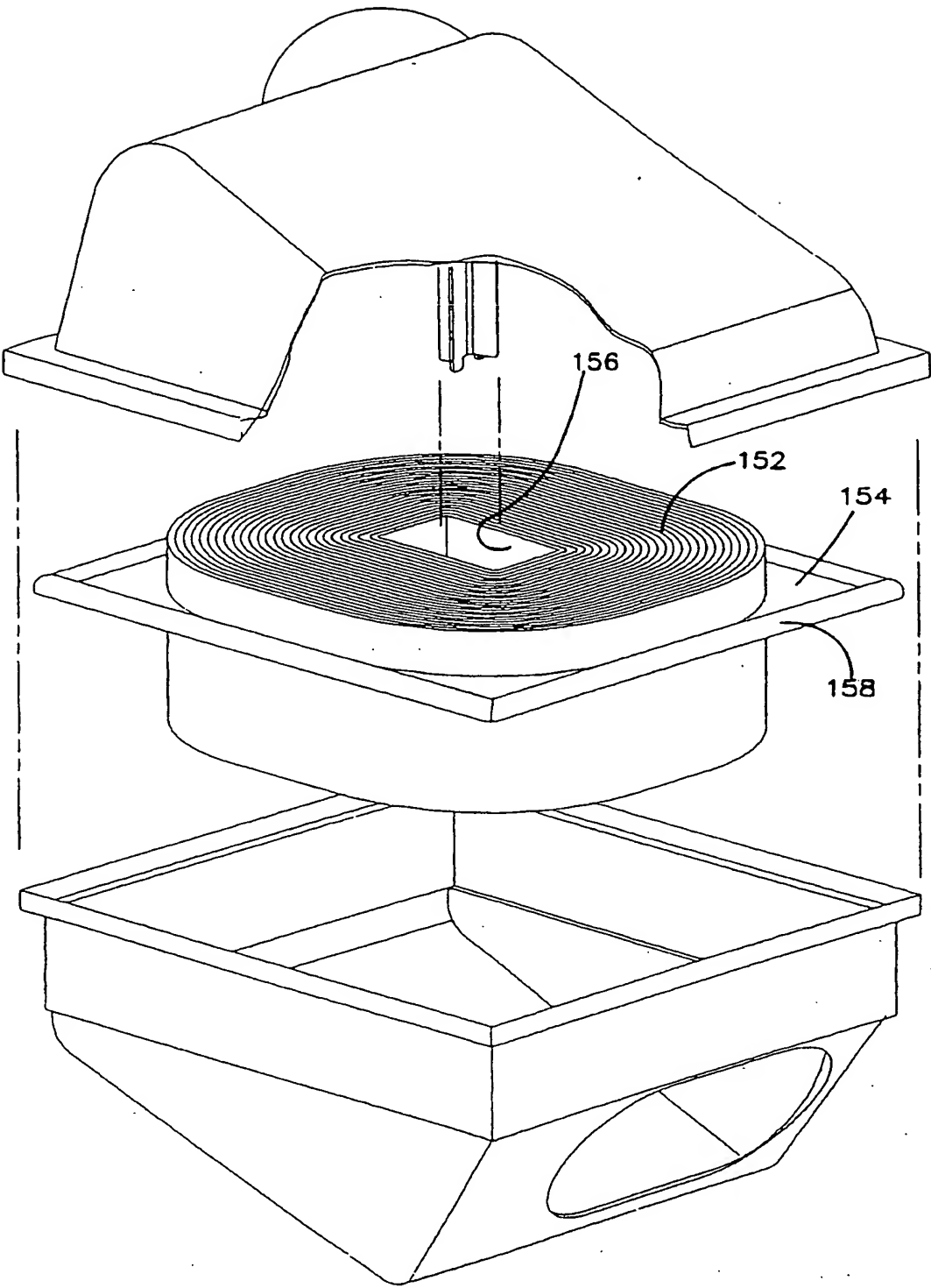


FIG. 16

12/17

FIG. 17



WO 97/40917

PCT/US97/06612

FIG. 20

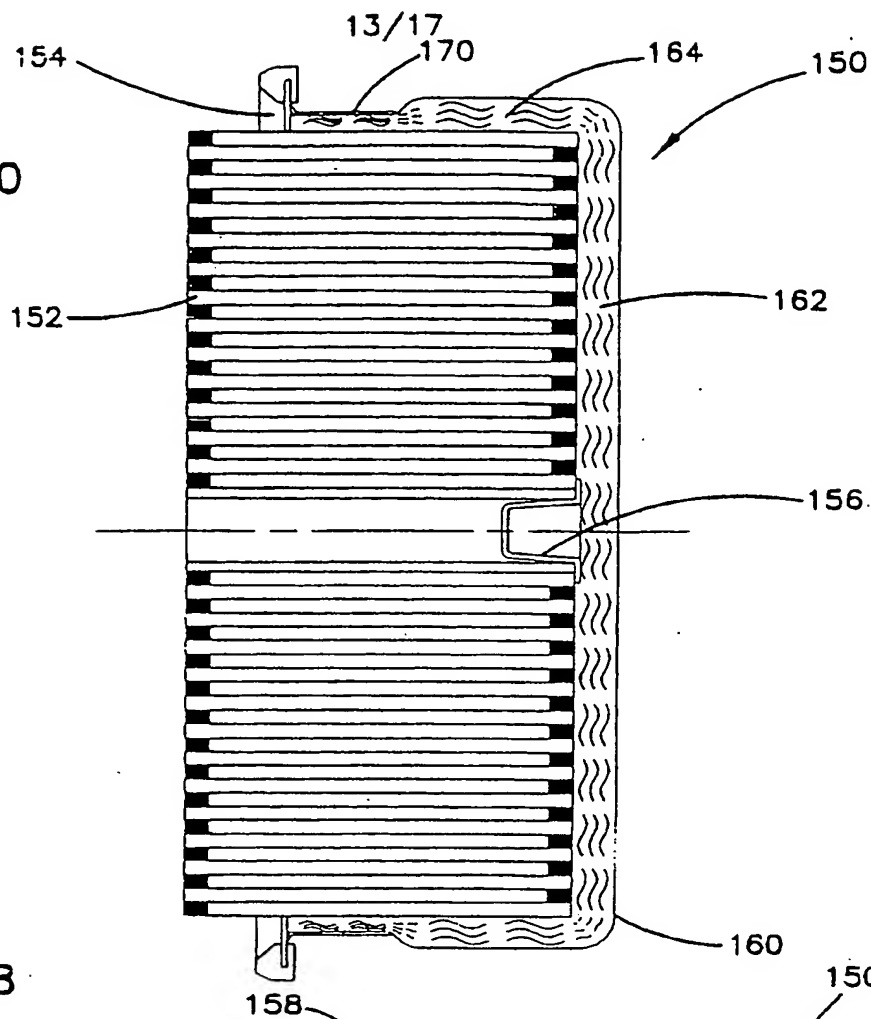
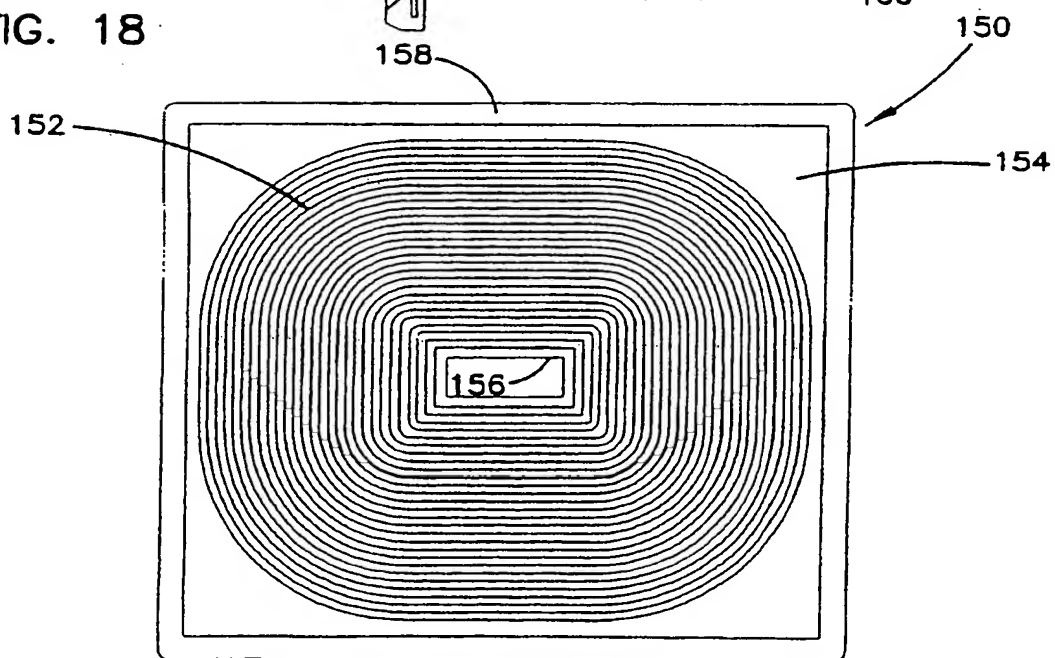


FIG. 18



14/17

FIG. 19

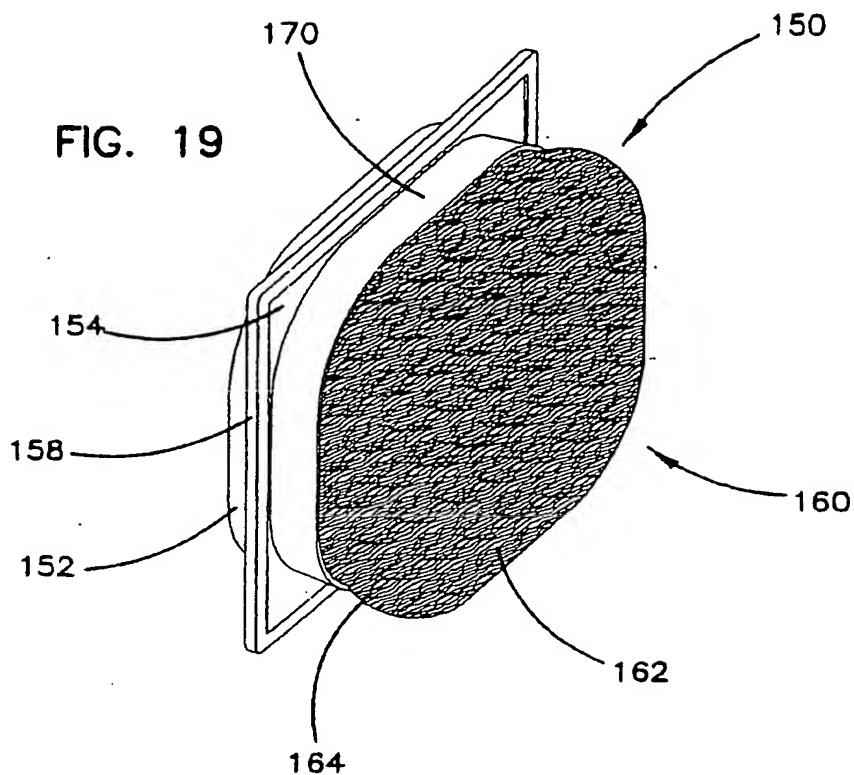
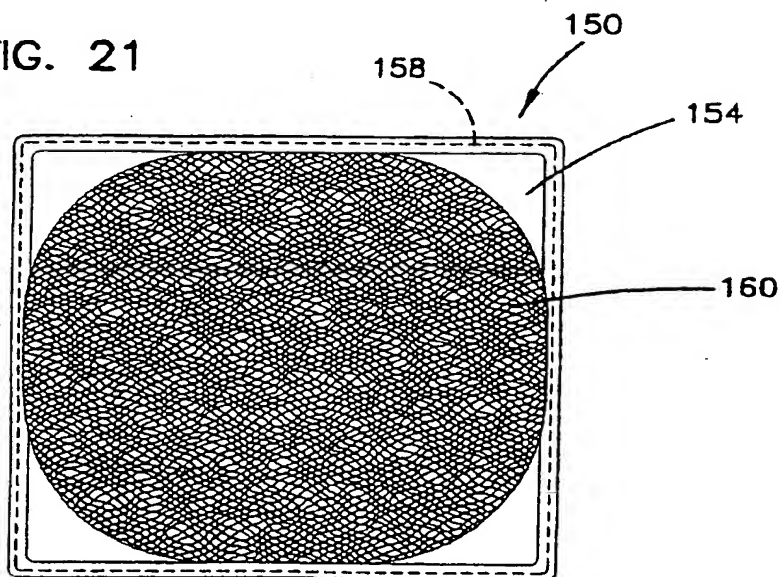


FIG. 21



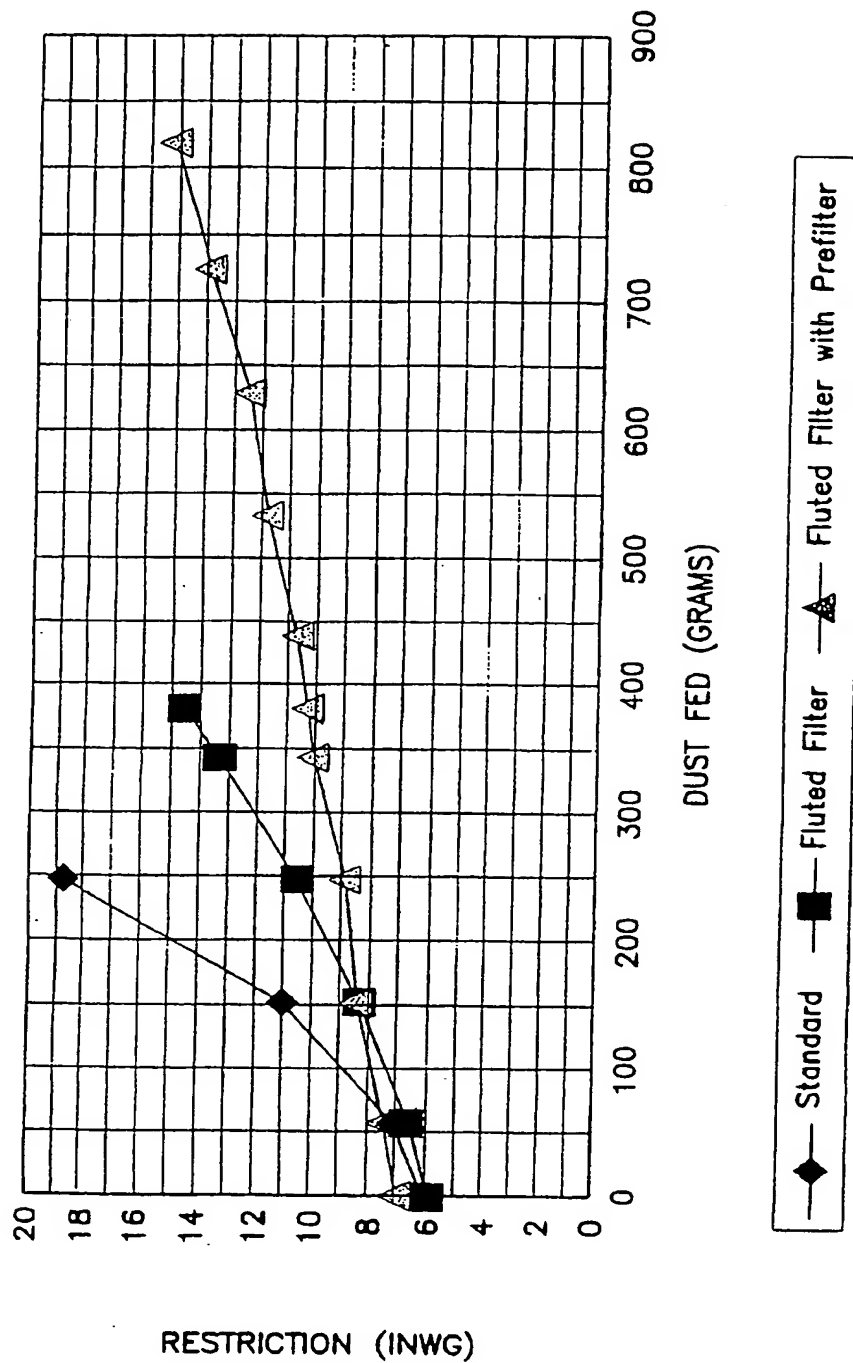


FIG. 22

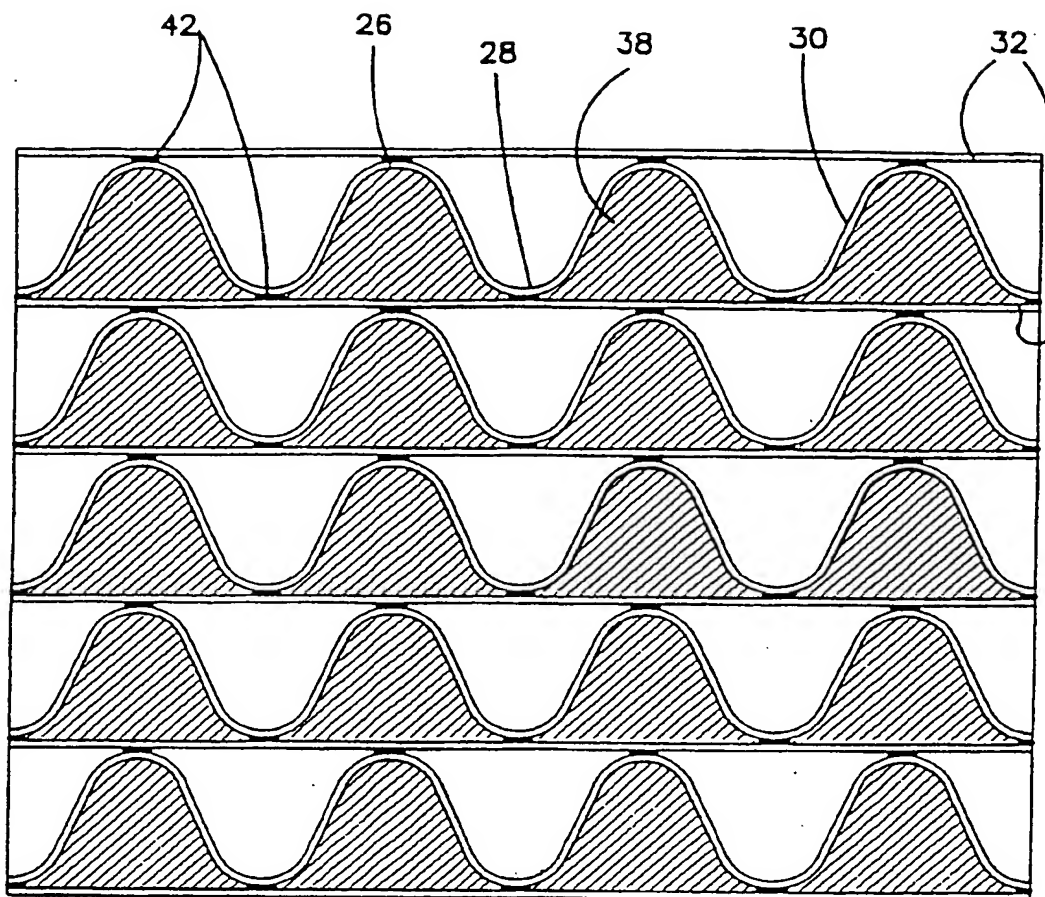


FIG. 23

FIG. 26

17/17

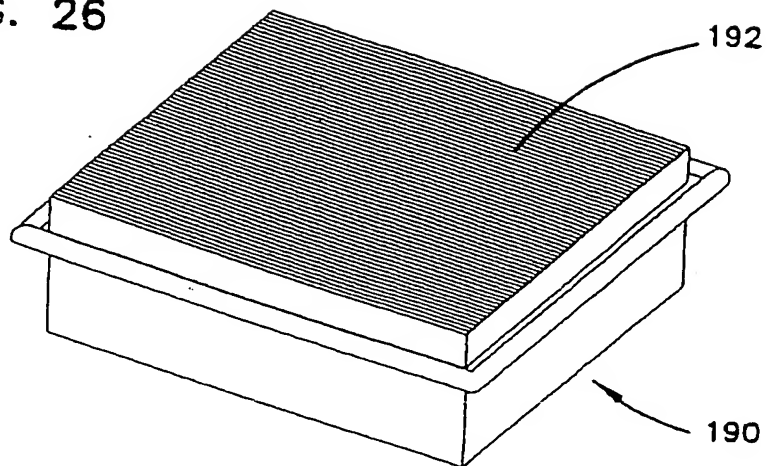


FIG. 24

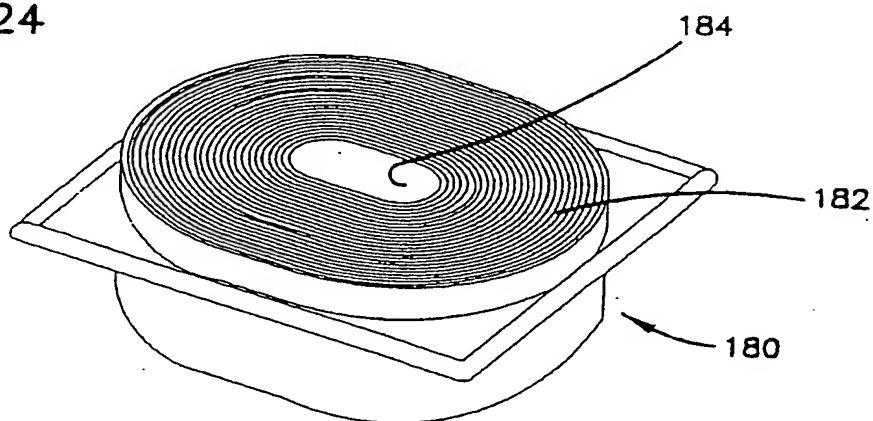
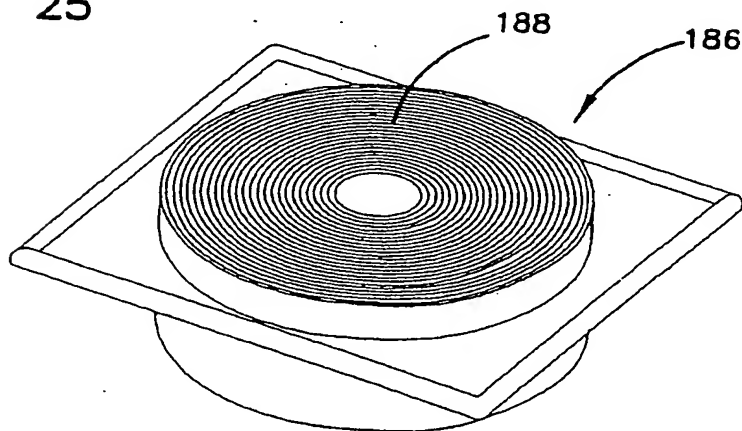


FIG. 25



## INTERNATIONAL SEARCH REPORT

Int. l. Application No.

PCT/US 97/06612

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B01D46/12 B01D46/52 B01D25/24

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 599 604 A (BAUER ET AL.) 10 June 1952  see the whole document ---	1-4,6-8, 14-16, 18-20, 22-24, 28,33,34
X	US 3 025 963 A (BAUER) 20 March 1962  see the whole document ---	1-4,6-9, 13-16, 18-20, 22-24, 28,29, 33,34
-/--		

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

\*Z\* document member of the same patent family

Date of the actual completion of the international search

6 August 1997

Date of mailing of the international search report

26. 08. 97

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+ 31-70) 340-2040, Tlx. 31 631 epo nl.  
Fax (+ 31-70) 340-1016

Authorized officer

Cubas Alcaraz, J



## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 97/06612

## C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 83 01582 A (DONALDSON CO INC) 11 May 1983  see the whole document ---	1,2,4,6, 9,13-16, 19,20, 22-24, 28,29, 32-34
A	EP 0 059 562 A (NIPPON DENSO CO) 8 September 1982 see page 5 - page 7 see page 15, line 4 - line 13; figures 1-4,31 ---	1,10,23, 27,28,33
A	EP 0 625 367 A (RAPP PETER) 23 November 1994 see abstract; figure 1 ---	12
A	EP 0 630 672 A (NIPPON DENSO CO) 28 December 1994 see claims 1-20; figures 1-12 -----	1-34

## INTERNATIONAL SEARCH REPORT

Int. Patent Application No.

PCT/US 97/06612

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2599604 A	10-06-52	NONE	
US 3025963 A	20-03-62	NONE	
WO 8301582 A	11-05-83	US 4410427 A	18-10-83
		AU 548875 B	02-01-86
		AU 1014283 A	18-05-83
		BR 8207950 A	04-10-83
		CA 1169362 A	19-06-84
		DE 3249151 A	12-01-84
		FR 2515526 A	06-05-83
		GB 2119672 A, B	23-11-83
		US 4589983 A	20-05-86
EP 0059562 A	08-09-82	JP 1022465 B	26-04-89
		JP 1702569 C	14-10-92
		JP 57140554 A	31-08-82
		JP 1683800 C	31-07-92
		JP 2039286 B	05-09-90
		JP 57140555 A	31-08-82
		JP 1666663 C	29-05-92
		JP 2000088 B	05-01-90
		JP 57140617 A	31-08-82
		JP 1038528 B	15-08-89
		JP 1640812 C	18-02-92
		JP 58074122 A	04-05-83
		JP 1016335 B	23-03-89
		JP 1615552 C	30-08-91
		JP 58074864 A	06-05-83
		JP 1745351 C	25-03-93
		JP 2018127 B	24-04-90
		JP 58074123 A	04-05-83
		EP 0152513 A	28-08-85
		US 4498989 A	12-02-85
		EP 0058994 A	01-09-82
		US 4430223 A	07-02-84
EP 0625367 A	23-11-94	DE 9307614 U	26-08-93
EP 0630672 A	28-12-94	JP 6327910 A	29-11-94

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 97/06612

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0630672 A		AU 669978 B	27-06-96
		AU 6321294 A	24-11-94
		CN 1100776 A	29-03-95
		US 5562825 A	08-10-96
-----			

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☒ **BLACK BORDERS**

☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

☐ **FADED TEXT OR DRAWING**

☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**

☐ **SKEWED/SLANTED IMAGES**

☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**

☐ **GRAY SCALE DOCUMENTS**

☒ **LINES OR MARKS ON ORIGINAL DOCUMENT**

☒ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**